Hand Pumps Problems in

Maintenance & Management and Operation

(Northern Kordofan, Northern Darfur, Bahar El Jabal and Nahr AL Niel States)

BY

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Dedication

To all who suffer fetching water from long distances

Water is the essence of life

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ABSTRACT

The study focused on maintenance & management problems of the hand pumps utilized in Sudan for provision of safe drinking water to the rural communities. The performance of different types of pumps were studied including India MarkII, Afridev and the locally produced handpump Atbara Type.

This study suggests many solutions to hand pumps problems that affect performance and serviceability of the pumps, like pump design, maintenance and management.

The research addressed the management issues related to the rural communities' subscription in the management of the yard (hand pumps), maintenance water point and collection of water tariffs.

Also this study suggested specific mechanisms for collecting water tariff from beneficiaries and how to distribute it to meet may thing issuses like spare parts, maintenance fees and labour incentive .

The research gives brief concept of establishing repair parts cell centre inside any communities, beside training for the villagers to assist in increase of the skill handpump mechanics.

The draw down of water table in some borehole damaged inner parts of pump. Brief suggestion to minimize the draw down phenomenon was given.

All these above suggestion is solution to many hand pumps problems and it can assist in sustainability of water point serviceabilty for long time.

ملخص الرسالة

الرسالة تختص بدراسة المضخات المستعملة داخل السودان لتوفير مياه الشرب الصالحة النقية لمواطن الريف وشملت الدراسة اداء المضخات و هي اانديا مارك ، و افروديف و المصنع محليا مثل عطبرة تايب.

وتهتم هذه الدراسة بتقديم الحلول لبعض المشاكل التي تؤدي الى تقليل الكفاءة و الاداء العام بالنسبة للمصدر و التي تتمثل في التصميم و الصيانة و الادارة.

و اهتمت الدراسة بوضع مقترح اداري شامل بمشاركة كل من المستفيدين من سكان القرى و المجتمعات و ذلك لادارة مرافق المياه المتمثلة في المضخات اليدوية ادارة كاملة من اشراف و صيانة و جمع تعريفة المياه.

كما اهتمت الدراسة بوضع الية جديدة لجمع و توزيع تعريفة المياه المجمعة من مصادر المياه على الاحتياجات الضرورية المتمثلة في قطع الغيار و الصيانة و الحوافز الخاصة بالعاملين.

كما قدمت الرسالة مقترح لانشاء مركز توزيع قطع الغيار بالمجتمعات المستفيدة من خدمات المياه قدمت الرسالة مقترح تدريب بمشاركة كل المستفيدين من الجنسين و ذلك لتوفير اكبر عددية من الكفاءة.

اهتمت الدراسة بظاهرة الجفاف الذي يصيب بعض الابار المزودة بالمضخات ويؤثر علي الاجزاء الداخلية و قدمت مقترح كيفية التقليل من هذه الظاهرة.

هذه المقترحات التي قدمت هي بعض الحلول لمشاكل المضخات اليدوية لكي تساعد في استمرارية المصادر والخدمات لاطول فترة ممكنة.

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ABBREVIATIONS

ADRA	Adventist Development and Relief Agency
ADS	Area Development Scheme
AMA	African Muslim Agency
APC	Area Project Coordinator
A.P.I	American Petroleum Institute.
ASTM	American Standard.
BS	British Standard
CARE	Cooperative Assistance and Relief Everywhere
CFVI	Child Friendly Village Initiative
cm	Centimeters
DWL	Dynamic water level
DIN	German Standard
F	Force {N}.
Goal	Aid Organization
H.F.P	Head Fulcrum pin
H	Head of Water {m}.
ICRC	International Committee of Red Cross
ILO	International Liberation organization
ISO	International Specification organization
IRC	International Rescue Committee
KAP	Knowledge Attitudes and Practices
kg.f	Kilogram Force
lit	Liters
mm	Millimeter
MSF	Medicines Sans Frontiers (France Medical organization)
m	Meter
MARKII	Mark two
MICS	Multi Inductor Cluster Survey
NGO	Non- Governmental Organization

NWC	National Water Corporation
Oxfam	Aid Organization
PVC	Polyvinyl Chloride pipe
pH	Hydrogen ion concentration
ppm	Partial Per Million
SD	Sudanese Dianrs
SCF	Save the Children Fund
SFM	Sweden Free Mission Organization
SKAT/HTN	Swiss Center for development Cooperation in Technology and management/ Hand pump Technology net Work
SWL	Static water level
TOT	Training of trainers
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children Fund
VLOM	Village level operation and maintenance
VHCs	Village Health Committees
WFP	World food Programme
WES	Water and Environmental Sanitation
WHO	World Health Organization
uPVC	Unplasticized Polyvinyl Chloride Pipe (Units)
γ	Kinematics viscosity {m^2/sec}.
ℓ	Water Density {1000 kg/m^3 }.

CHAPTER ONE

INTRODUCTION

1.1- Introduction

Sudan is the largest country in Africa. Topographically, Sudan is a flat plateau gradually sloping towards the north and at the same time sloping from east to west towards the Nile River which traverses the entire length of the country from south to north. It is the most important physiographic feature in Central Sudan.

The altitude, countrywide, varies between 300 and 600 meters, above sea level, but in the mountain areas (Western and Red Sea) the altitude could reach up to about 3,000 m [9].

The climate is tropical varying from desert in the north to savannah zones in the south. The temperature can reach 52 ^{0}C during the summer with a mean daily winter temperature of 16 ^{0}C in the north and 29 ^{0}C in the south. Rainfall is seasonal and ranges from almost nil in the Northern desert to 1500 in the extreme south [39].

The population of the Sudan has grown two and half times since independence, from 10.26 million in 1955 - 1956 up to 25.6 million in 2000, with recognizable rural migration to urbanized zones. The major reasons for high rate of rural – urban migration are drought, civil conflict, lack of drinking water and declining development investment in rural areas.

Late survey carried out at country level to assess the rural domestic water supplies revealed that about 47% of the rural and 73% of the urban population have access to safe water supplies [14]. The majority of the rural populations are fetching water from underground water sources by means of powered pumping units (water yards). These water services equipment have greatly deteriorated due to ageing of the equipments, shortage of spare parts and consumptions, the dated centralized management system and lack of community participation in these technology options;

Also the operational costs of such water yards are extremely high and not at the reach of the rural communities [40].

The responsibility for financing the operation and maintenance of existing water sources has fallen heavily upon a substantially weakened public sector, where efforts to generate revenues from users have not succeeded. Income has rarely covered less than 40% of real annual costs and shortages of hard currency for purchase of essential spare parts and fuel have resulted in more than 70 % of the systems functioning doing at less than 50% capacity. Within this context, the government began to seek low-cost technology options for rural water supply, encouraged by favorable reports of community-managed hand pump water supply programmes in India and elsewhere in the African continent [36]. The enthusiasm was initially guarded and supported by donation from foreign countries in the use of low-cost technology and participation of the community in construction, operation and maintenance of facilities. The involvement of many organizations in supporting government efforts to supply sufficient water to its rural population resulted in drilling over sixteen thousands boreholes and fitting them with hand pumps.

Moreover the country used to depend on the external donor agencies which provided more than 80 % of the federal required. This dependence is squeezed and the part of these donation organizations handed this water point to the communities through the state water corporation, with different types of operation and different maintenance model implemented.

The decentralization of the management and maintenance system of the hand pumps to the village level resulted in more dysfunctional hand pumps.

1.2-<u>Objectives of The Study</u>

The main objective of the study is to investigate the actual factors that affect the efficiencies and sustainability of the hand pumps including technical design, maintenance and management procedure.

The research is a trial to improve the hand-pumps efficencies and raise their capabilities for sustainable safe drinking water to the rural communities' and improve the socio – economic situation. The specific objectives of the study are:

1. To modify some parts of the hand pumps to suit Sudan water formation and to minimize frequent hand pump breakdown.
2. To formulate management system involving different stakeholders including rural population, local authorities and state governments.
3. To establish new system for operation, maintenance and management procedure to ensure smooth provision of water.
4. To establish suitable water tariff collection system.

1.3 <u>Location of the Study Area</u>:

The study areas were located in Northern Darfur State (El Fashir and Abu Zrake Village), Northern Kordofan State (North and East El Obied), Bahr El Jabal State (Juba) and Nahr Al -Niel state (Atbara and El Damar) as shown in the Fig. (1-1).

1.4 <u>Population</u>:-

The distribution of the population in the study area is mainly controlled by availability of water and pasture. During the last 15 years a high migration of the people moved towards El Obied , El Fashir and Juba as a result of drought, desertifictaion and civil conflict in the area [12].

The main tribes are Fur,Zaghawa, Tungor, Arabia Bashiria ,Bartee in Northern Darfur. Bedaria, Goama in Northern Kordofan. Bari, Latuka, Morelle,in Juba. Galyei and Rubatab in Nahr Al -Niel.

1.5- Climate: -

The study areas is within drought-prone, sub- Saharan Sahel zone and poor Savannah, the climatically highly sensitive transition zone between tropical rain forest and the Sahara. The area is characterized by a step increase of the annual rainfall (Summer rains from July to September) from few millmeter at northern margin to approximately 800 mm at the southern margin [42].

Winters are cool and lacking any precipitation with average over night temperature ranging from 10 ^{0}C to18 ^{0}C in January with dusty winds (haboob) blowing mainly from north [12].

Summer is hot with a maximum day temperature of more than 40 ^{0}C in May –September. Because of the northward migration of the intertropical convergence zone, the wind pattern changes and the wind blowing from the southern direction.

Thus during the year the dry winter north winds alternate with the moist summer winds from the equatorial convectional cells, which cause precipitation during summer.

The mean annual temperature ranges between 36-46 ^{0}C and the mean annual relative humidity of the air ranges between 9%-20% in the North (latitude 16^0-22^0N) , 14-40% in the middle (Latitude 10^0-16^0N) and 20-80% at latitude 10^0N [39].

1.6-Material for the Study

Most of the material used in this study, including data and analysis, are obtained from the field work, WES UNICEF office, WES projects at states and rural water corporation at states level.

1.7-Method of Investigation

The method of investigation adopted in the present work includes the field works together with laboratory test shown in the Fig (1-2).

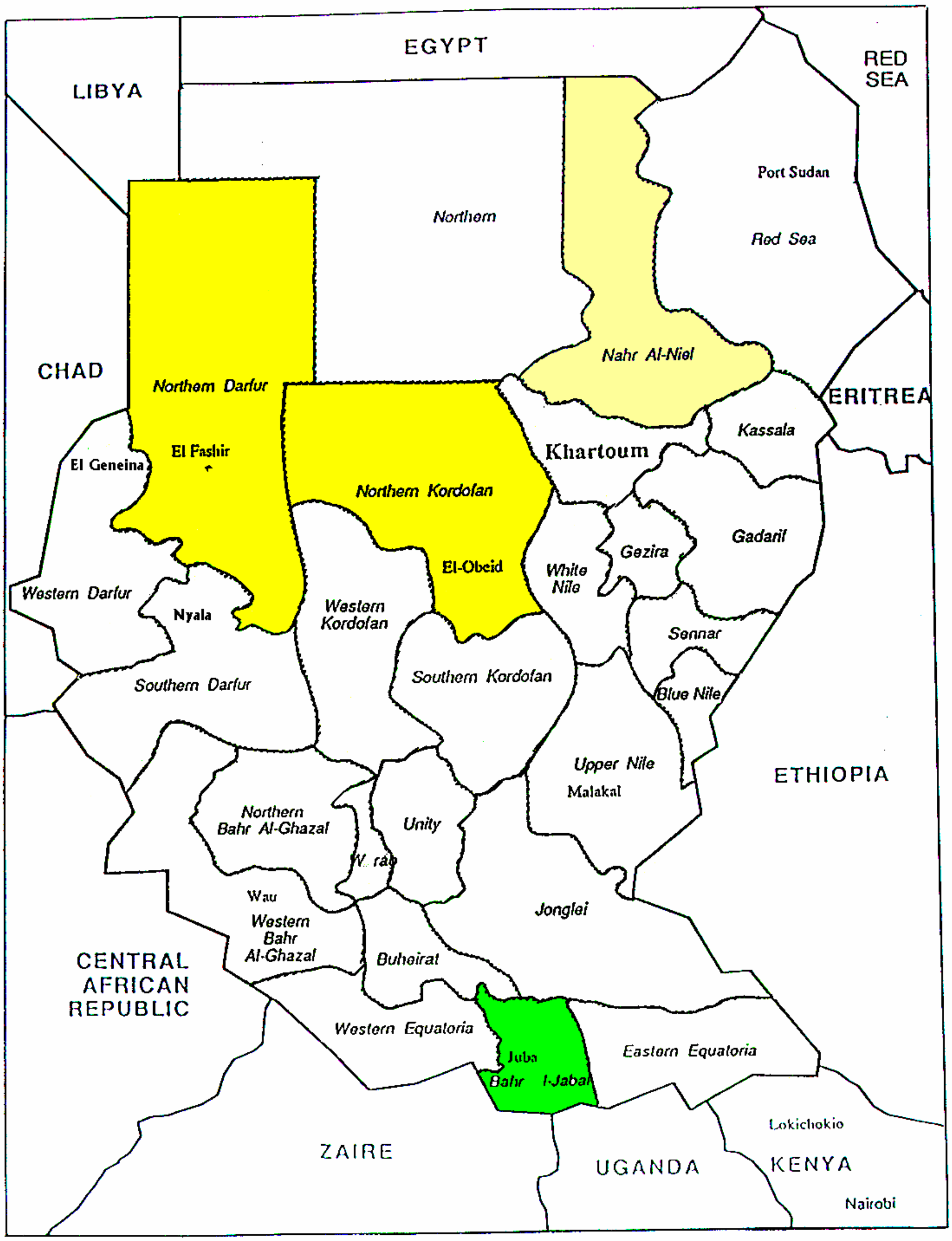


Fig. (1-1) Select Area for the Study

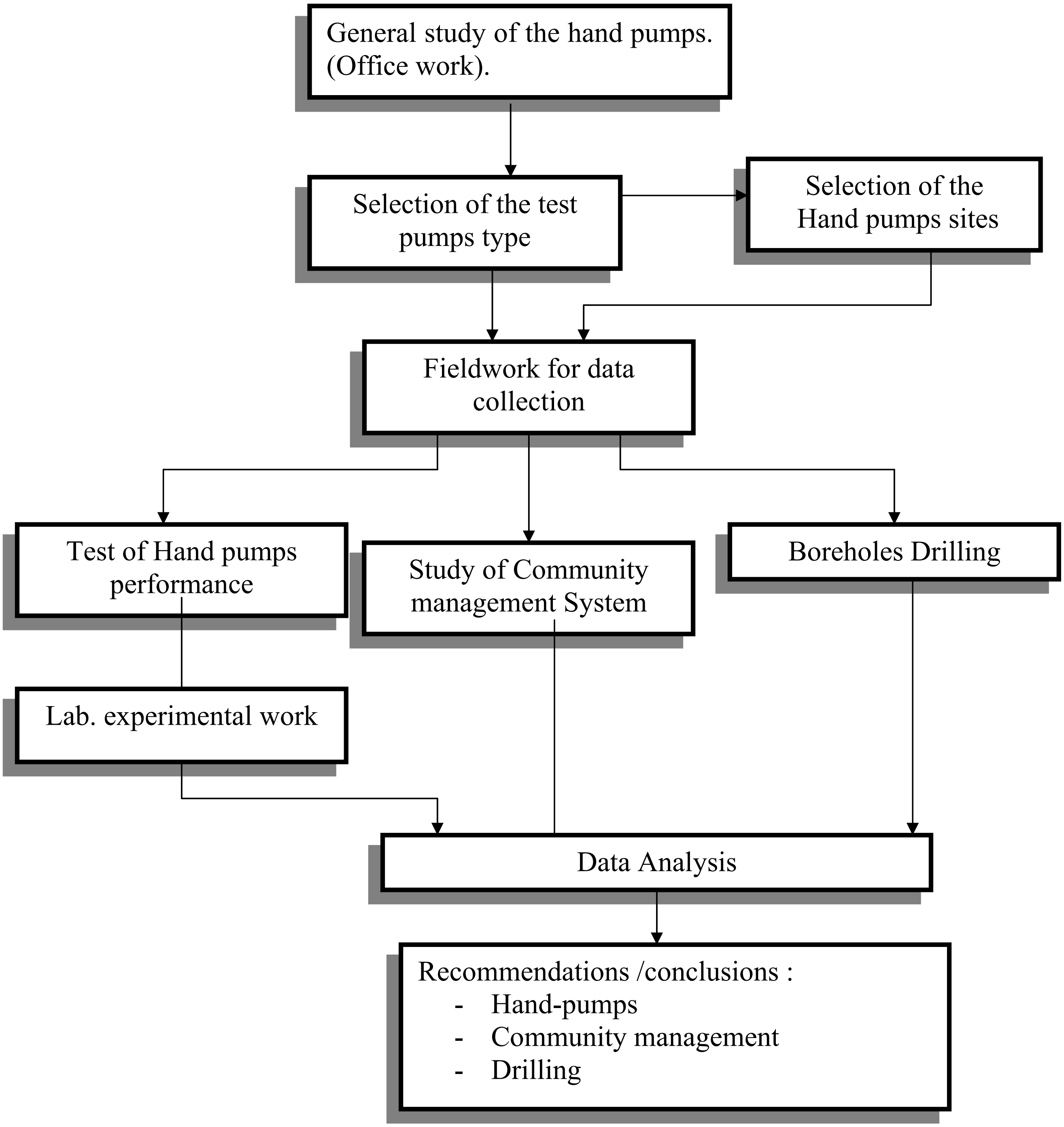


Fig. (1-2) Illustration of the Basic Approach of the Study

Chapter II

CHAPTER TWO

WATER ACTIVITY IN SUDAN

2.1 Introduction

Generally, two conditions should be available to have abundance of ground water supply.First the local geological conditions must be suitable for storage and transmission of large volume of water. Second the hydromaterogical conditions must be favourable enough to keep aquifers recharged. The volume of groundwater is affected by the presence of prevailing climate. The following is a breif summary on techincal aspects.

2.2 Water Bearing Characteristics

The major water bearing rocks in the selected areas are compromising the following strata:

a. Alluvial Deposits

These alluvial deposits represent the shallow aquifers.

b. Um Ruwaba Formation

The Um Ruwaba Formation consists of unconsolidated sands or gravelly sands and clays. Um Ruwaba Formation has a wide occurrence within the Bagara basin. Water is acceptable from Um Ruwaba sediments penetrating more than 200m, which are composed of variety of coarse and fine grained, well sorted and poorly sorted sands.

c. Nubian Sand Stone Formation

This formation consists of consolidated sands, sometimes-gravelly clay sands and clays**.** Nubian Sandstone formation has a wide occurrence. The ground water is good in terms of quality and quantity, with multi aquifers at various depths.

d. Basement Complex.

Water extracted from the weathered part of this formation. In addition, water is obtained from the fractures of the rocks (Secondary porosity). The water in term of quantity and quality depend on the size of fractures (secondary porosity) and type of the rocks.

2.3-Ground Water Basins:

The ground water basins are either in a simple or a complex form. according to the geological formations. There are six basins in Nubian sandstone formation : two in the Nubian/Um Ruwaba formation, eight in the alluvial deposits, two in the Um Ruwaba formation and two in Nubian/ basalt formation as indicated in the Fig [2-1].

Table (2-1) Groundwater availability in the geological formations [39].

Formation	**Area covered by formation in % of country area**	**Ground water availability**	**Water quality and suitability for human and animal use**
Basement complex	49	*Low*	Moderate
Nubian sandstone	28	High	High
Umm Ruwaba, Gezira	19	High	High
Other forms	4	Low	Low

The ground water potential in the Sudan is very high where large quantities of ground water available for future development.The unconsolidated sedimentary rocks yield large quantities of water and the basement complex rocks with low yield means suitable for hand pumps with a maximum extraction of $1m^3/hr$.

Sudan water potential estimate is about 900 billion m^3 of under ground water with an annual recharge of 4 billion m^3.

The present annual consumption of ground water is 1.2 billion m^3 that means a positive ground water budget [9].

Table (2-2) Characteristics of the Basins in Sudan [29].

#	Ground Water Basins	Depth to Water in (Meters)	Saturated Thickness (Meters)	Area covered by the Basin (Square Kilo meters)
1	**Nubian Basins** 1.Sahara Nile Basin 2.Sahara Nubian Basin 3.Central Darfur Basin 4.Nuhud Basin 5.Sag EL Na'am Basin 6.River Atbara Basin	 10-20 10-50 25-100 100-120 50-100 10-100	 100-500 100-1000 100-350 150-250 500-2000 100-500	 273,980 324,356 52,924 6,798 2,678 23,896
2	**Um Ruwaba Basins** 1.Sudd Basin 2.Eastern Kordofan	 10-25 50-75	 100-3000 100-500	 365,268 68,392
3	**Nubian Um Ruwaba Basins** 1.Baggara Basin 2.Blue Nile Basin	 30-75 10-50	 100-2000 100-500	 141,376 75,808
4	**Nubian/Basalt Basins** 1.Gadarif Basin 2.Shegara Basin	 50-75 25	 200-500 200-350	 28,016 , 824
5	**Alluvial Basins** 1.Nyala Kutum, Abu Gebeiha, Khor Barka and El Gash	 3-10	 10-50	

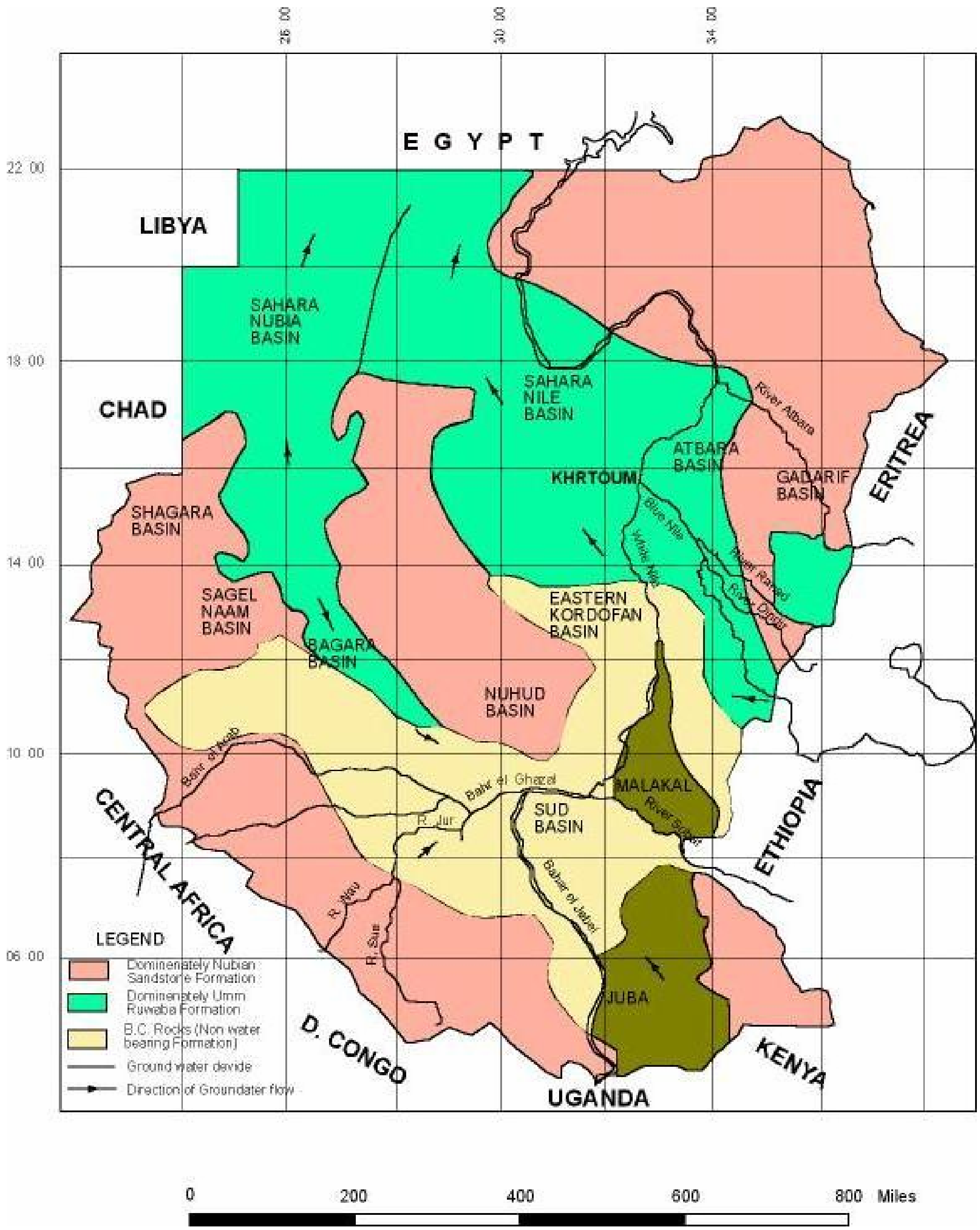


Fig. (2-1) Hydrogeology Map of Sudan [42].

2.4 Water Resources

Water resources in Sudan are subdivided in two main categories:- surface water and subsurface:

2.4.1-Surface Water Resources:

The River Nile, both White and Blue with their tributaries, are the main sources of surface water for domestic water supply to cities and villages near the riverbanks.

Another source of the surface water (rain harvesting) is water collected during rainy season in Haffirs, Folas, Dams and Natural Ponds.

2.4.2-Ground Water Resources:

Ground water resources are estimated at a round 900 billion cubic meters with annual recharge of around 4 billion cubic meters. A large proportion of the population of the Sudan relies on ground water as the main water resource for multipurpose projects, industrial, irrigation and livestock. The ground water resources development is expensive compared with surface water.

At the present time, rural populations are served from different water resources including water yards with boreholes, Haffirs, shallow wells equiped with hand pumps, hand dug wells with rope and bucket, rivers , stream, canals and open natural pools as mentioned under:-

1.Water Yards:-

A bout 8000 water yard boreholes have been drilled in the Sudan from year 1919 up to now with approximaty average depth of 90 meter, with inner borehole casing diameters range between (15.24cm-33.02cm), and equipped with reciprocating pumps or turbine or submersible pumps supplemented by diesel engines [25].

The major operation and maintenance problems are finance, age of equipment, lack of development capital and high costs of spare parts associated with shortage of staff [8].

2. <u>Open hand dug well</u>:-

The open hand dug well is the traditional form of improved water supply in the Sudan. Many of the these wells have a depth which covers up to 40m and the diameter varies between 0.9-3m lined with wood or lately by cement and bricks or unlined. Water is lifted in a bucket by use of a rope or hand-pumps.

3. <u>Haffir</u>:-

The surface water is diverted during the rainy season into impoundament. It can be considered as a form of rain water harvesting. Haffirs are excavated in preferably impermeable soil with sizes ranging from 5000 to 100,000 m^3 with depth varying from 3 meters to 8 meters . The evaporation losses are high and most of it are supplying untreated water to the users.

4. <u>Boreholes Mounted with Hand pumps</u>:-

The first hand pump scheme construcred in the mid of 1970s in the southern Sudan as a simplied technology in terms of design, instllation, operation & maintenance. These hand-pumps mainly located in the basement complex with low yields. With assistance of the World Bank donation in 1972, the drilling of shallow and deep wells mounted with hand-pumps was increased. Since 1976 UNICEF water program began interm of planning funding and implementation of boreholes equiped with handpumps in southern Sudan. The programme started with limited government contribution, initiated by drilling some boreholes in Equatortia region in 1977, then the program area moved to Bahar El Gazal region and extended to South Kordofan State. With an agreement between the government of the Sudan, the World Bank and the UNICEF in march 1992, the (WES) program was expanded to other regions including Darfur and other Kordofan States.

Due to the success made by the WES program in supplying safe drinking water to the most needy communities through hand-pumps, many non Governmental Organizations (NGos) contributed in the drilling, installation and maintenance activities of hand- pumps. These NGos include:-

Table (2-3) Organizations working in Hand pump technology

#	Organization	Working Region	Type of Assistances
01	ADS	Southern Darfur, El Damar , Northern Kordofan	Drilling , installation and maintenance of hand pumps
02	SCF	Southern , Northern Kordofan	Maintenance of hand pumps.
03	CARE	Southern Kordofan, Northern Kordofan (Elobied, Um Ruawaba)	Maintenance of hand pumps
04	MSF	Southern Kordofan , Kadugli , El Obied and Southern Sudan	Maintenance of existing hand pumps. And drilling new boreholes,
05	GOAL	Southern Sudan, Juba. Wau	Maintenance and Training of pumps mechanics
06	OXFAM	Southern Sudan Juba.Wau	Maintenance and training communities.
07	HELP AGES	Southern Sudan Juba.	Maintenance and training of hand pump mechanics
08	ADRA	Khartoum IDP.	Drilling, installation and maintenance hand pumps
09	ILO	Kordofan	Drilling, installation and maintenance of hand pump
10	RED CROSS	Kordofan.	Drilling, installation and maintenance of hand pumps
11	RED CRESSENT	Southern Sudan	Drilling, installation and maintenance hand pumps
12	AMA	Southern Kordofan	Drilling new Boreholes
13	SFM	Southern Sudan	Drilling, installation and maintenance hand pumps

The Policies, strategies and objectives for all organization were designed to achieve their goal as a final aim but coordination / integration with other partners in the same field will accelerate the pace of the organization in achieving these goals. With this understanding, coordination and linkage with government water department and NGos became essential to exchange experiences for optimum utilization of available resources and providing techical assistance. All these organization and agencies are working under the umbrella of the water program at the states or regional levels coordinated from National Water Cooperation in drilling, installation and training.

According to available data approximately 16,000 boreholes had been drilled in the Sudan to the year 2000. To an average depth of about 50 meters or less below the ground surface making them suitable for low cost hand- pumps option.

The present rate of expansion of water services doesn't keep pace with the increasing demands due to urbanization and population growth. This implies that unless there is a significant increase in the resources allocated for the water sector and unless they are used cost effectively, meeting the set goals of universal access to adequate and safe water will not be achieved. Provision of water is an effective tool to resolve tribal conflicts, community's stabilization, and rational utilization of all available natural resources.

2.5-History of the WES Programme

UNICEF has been involved in water, environment and sanitation (WES) issues since the 1960s. Its first major sectoral interventions were in response to a devastating drought in northern India 1967. Since then, UNICEF has supported longer-term WES programming initiatives in some 90 countries in Asia, Africa and the Americas. The overall objective of UNICEF within the water and sanitation sector is to promote the survival, protection and development of children, and to promote behavioural changes essential to realizing the full benefits from WES services.

Sudan was the first African country to receive UNICEF assistance in the field of water and environmental sanitation. The objective was to assist women and children, among other needy groups to have access to safe drinking water, in order to improve their health status.

The programme started in Southern Sudan in 1975, when a hand pump installation project was planned for Equatorial Region.Project implementation began in 1976 and was extended in mid-1977 to cover Bahr Al-Ghazal region, Since that time, the programme has expanded to reach the following areas in both southern and northern Sudan:-

- Kadugli Area in Southern Kordofan region in 1978.
- Sinkat and Red Sea in 1985.
- Northern and Southern Kordofan regions in 1986.
- Darfur State in January, 1992.
- Central (Sennar and Blue Nile) States in August 1992.
- White Nile State in 1995.
- Gezira, Gadarif and Khartoum States in 1997.
- Kassala State in the year 1998.

The programme has extended to include 16 states, where the demand for water and sanitation is high, as follows:-

Southern Area:	Upper Nile, Equatoria and Bahr El Ghazal states.
Darfur Area:	Northern, Western and Southern Darfur states.
Kordofan Area:	Northern, Western and Southern Kordofan States.
Central Area:	Blue Nile,White Nile, Gezira, Sennar, Gadarif and Kassala States.
Khartoum Area:	Khartoum State.

The WES programme in the Sudan was completely driven by and fully dependent on UNICEF assistance, in terms of planning, funding and implementation, with only a limited participation and contribution from government and communities. In consequence, government and communities had only a limited awareness of the programme concepts and objectives.

During the initial phase of the programme, the main focus was on hardware, especially on the construction of water schemes and important aspects such as sanitation, hygiene, health education, women's participation, social mobilization and programme sustainability.

In the mid eighties, the WES programme started to advocate vigorously for community participation and management and therefore, adaptation of technology towards what is low-cost simple and appropriate. To the water provision program is added health education and sanitation, making one package. However, the programme is still centralized and highly concentrated in limited areas, with little government or community inputs.

More recently, the WES programme has focused greater efforts towards child survival, protection and development, along with the lines of the International Drinking Water Supply and Sanitation. Through the following:

- Supporting efforts to achieve universal access to safe water supply and environmental sanitation services as part of the basic rights of children.
- Promote the behavioural changes essential to realize the full benefits of such services;
- Strengthening women's participation, contributions from communities and local councils cost recovery and appropriate technologies.
- Strengthening funding through decentralization: since 1994, foreign support to the sector has been drying up and UNICEF funding shrinking, with the decrease of money for regular components. This has happened against a national context of a critical economic situation and civil conflicts. These trends have necessitated major changes in programme

strategies to find other ways of funding and sustainability. The first steps were the decentralization and institutionalization of WES activities to states level, to ensure states and community funding and involvement;

- Building capacity among counterparts, communities and relevant institutions training and technical support;
- Learning from partners such as NGos by sharing experience, concerns and constructive ideas to improve WES programme delivery mechanisms.
- Co-operating with the relevant national and international organizations and institutions.

1-**<u>Approach and Strategy of WES programme</u>:**

An underlying philosophy of the programme is to reduce dependency on foreign assistance, and programme ownership, paired with technology that is low cost, simple and appropriate. The main strategies include:

- Focusing more on the rural and peri-urban poor and emergency areas.
- Introducing and supporting low-cost and appropriate technology solutions.
- Integrating services (water, sanitation and hygiene education) to make package.
- Decentralizing of WES activities down to the community level.
- Strengthening of local capacities, especially those of community institutions and organizations, establishment of WES units wherever possible at the level of the Rural Council (Mahlia) and strengthening of the links between water – related institutions and the relevant health sectors at rural and at State level.
- Ensuring community ownership and management of facilities to ensure sustainability.
- Increasing the participation of women at all levels by promoting gender-sensitive strategies.

- Mobilizing government and community financial resources through service cost-sharing, revolving credit and water charges to ensure cost-recovery and sustainability.
- Collaborating with other agencies, UN organizations and NGOs.
- Establishing Monitoring and Evaluations Units in WES projects at state level and in government institutions to enable programmes to improve effectiveness and reduce operational costs.
- Replicating successful WES approaches in new areas.

Nowadays WES has a well defined institutionalized and decentralized structure. It’s structure starts at the WES Village Health Committees its representing the direct community participation in the programme. It goes then up through the WES units at the rural council’s level to WES states project level. It ends with the Federal WES level that is the National Water Corporation and the Federal Ministry of Finance which are assisted by UNICEF.

Chapter III

CHAPTER THREE

HAND PUMPS TECHNOLOGY

3.1 Introduction

The provision of safe drinking water supplies to the rural communities through the offshore technology options including the powered pumping equipments(Submersible, Turbine and Positive Displacement pump) deteriorated due to shortage of spare parts, difficult maintenance procedures, the high running cost utility and management process which affected the sustainability of the rural water utilities. As a result of this situation simple technologies include the handpump approach which could be operated and maintained at rural population level, so that sustainability of the rural water supply systems could be maintained .

The history of hand pumps goes a long time back, McJunkin reported that the use of positive displacement reciprocating pumps started in ancient Rome as early as 275 BC by making, wooden pump using metal flap Valves, from Saxony ,that was recorded by Agricola in the 16 century [20]. Then the techology has been developed a round the world to cover the need of safe drinking water of the population of each country. All the hand pumps manufactured by industrialized countries participated specially in the following purpose:-

- Easy maintenance by villagers' caretakers means requiring minimal skills and few tools
- Cost effective.
- The hand pump can be serviced by community.
- Pay the repair cost by the community directly .
- Decrease water borne diseases.
- Some parts can be easily manufactured in the country, primarily to ensure the availability of spare parts.

3.2 **Type of hand-pumps according to their working Principle :-**

Water moved by the different mechanical principle like:-

1- Direct lift:-Physically lifting water in a container such as in case of using a bucket and a rope

2- Displacement: - The water is effectively incompressible and can therefore be placed

3-Creating a velocity head

4- Gas

3.2.1 **Low Lift (Suction pump)**

With reference to figure (3-4) the suction plunger hand-pump has cylinder and plunger (or piston) located above the water level. The pump is primed by pouring water on the plunger . On the up-stroke of the plunger, the pressure in the suction pipe is reduced compared with the atmospheric pressure outside, pushes the water up into pipe. On the down- stroke a check valve at the inlet of the suction pipe closes and the water passes the plunger through the opened plunger valve. With the next up-stroke, this water is pushed up by the plunger and flows out at the top while new water flows up in the suction pipe. The barometric pressure and the effectiveness of the seals limit the maximum suction height.The suction pump has the following general specifiction :-

Lifting head 7 Meter under ground level

Discharge range from 0.4-0.6 L/s [32].

3.2.2 **Direct Action Pump**

With reference to figure (3-5). The direct action hand pumps are reciprocating pumps which can continue to operate when the water table has reach of suction pipe. The operator’s effort is applied directly to the plunger; the plunger at the lower end of the pump rod is located under ground-water level. On the up – stroke, the plunger lifts water into rising main and replacement water is drawn into the cylinder through the foot valve. On the down – stroke, the foot valve closes, and water passes the plunger to be lifted on the next up stroke. There is no need for priming, which is also an advantage over suction pumps. Without the mechanical advantage achieved through a lever or flywheel. This elimination of the mechanical advantage restricts application of direct action pumps to the depth from which an individual can physically lift the column of water.

This pump has the following general specification:-

Lifting head 12 meter

Discharge range from 0.25-0.42 L/s [7].

3.2.3 Intermediate and high lift

The deep well hand-pump, the piston is placed in a cylinder under the water level which is usually in the range of 15 to 45 m below the ground . The pumping motion by the user at the pump stand is transferred to the piston by means of a series of connecting rods inside the rising main. on the up stroke, the plunger lifts water into the rising main and replaced water is drawn into the cylinder through the foot valve. On the down - stroke, the foot valve closes, and water passes the plunger to be lifted on the next up – stroke as shown in figure (3-2) and figure (3-3) .Like India Mark II and Afridev. These pumps with the general specification or normally meets 45 -90 meters in depth (modified India MarkII) with Discharge 0.36 L/s [7,32].

3.2.4 Diaphragm pumps

Inside a cylindrical pump body at the bottom of the well, a flexible diaphragm shrinks and expands like a tube shaped balloon, taking the water through an inlet valve and forcing it out through an outlet valve connected to a flexible hose which leads it to the surface .The movement of the diaphragm is caused by a separate hydraulic circuit consisting of a cylinder and piston in the pump stand, and the water –filled pilot pipe which is also a flexible hose. The piston is moved, usually pushing down a foot pedal, although conventional lever handles may also be used to apply such force. when foot pressure is removed , the elasticity of the diaphragm forces water out of it and back up the pilot pipe as shown in the figure (3-6). This pump has the following specification :-

Head less than 20 m

Discharge range from 0.24-.50 L/s [15].

3.3 <u>Back Ground for the Two main Hand pumps in Sudan</u>

The first hand pumps uitilized in Sudan are (Uganda handpump, Dempster, Blair Derivative , Mono , India MarkII , INALSA, Monarch, Petro and SWN 80) [21] . All these mention types not worked too long because some were collapsed.

After the introduction of the new technology, most of the old types being changed by new models like India MarkII and Afridev hand pumps. So that, these two types became the most popular pumps in Sudan with local manufacturing Atbara type.

3.3.1 <u>India MarkII Hand pump</u>

The pump in figure (3-2) is widely used in India and increasingly being installed in other countries. The pump stand is a galvanized fabrication with a straight steel handle that provides 8: 1 mechanical advantage, the pump is distinguished by the chain and quadrant link between the handle and pump rod, which depends on a gravity return to affect the down stroke. Ball races are used for the handle bearings. The steel pedestal is concreted into the pump apron. The below- ground assembly is conventional with a brass- lined cast iron cylinder 63mm for pumping lift 45 or 50mm cylinder used for pumping lift between 45m and 60m. The standard pump has galvanized steel pump rods (12mm) and 32mm rising main. The rod and rising main must be removed to extract the cylinder and foot valve incorporated in the lower of the gunmetal end caps. This pump evolved from design first introduced by Sholapur well Service non government organization. A standard design emerged in the mid of 1970 and field tested by UNICEF; late in 1977 Richardson and Crudass (an Indian government company [30]. began manufacturing the design approved by UNICEF. This was named the India Mark II. The design is continually improved through field testing and revisions to the specifications. Today about 40 approved Indian manufacturs are producing the hand pumps. The India MarkII is sturdy and reliable, and with UNICEF support, it has become the standard village level hand pump in India. It is also being used in other parts of Asia and India, where million or more MarkIIs are in use throughout the country, Chain lubrication and tightening of nuts accounted for most of the routine-maintenance operations, and plunger seal replacement were the most common repair needed in the India Mark II The modification done by replacement of the standard leather cup seals with nit-rile rubber cup seals, which are more abrasion resistant and do not swell but the India Marklls main problem is corrosion of below- ground components. The galvanized steel pump rods and rising mains fail victims to the regions corrosive water.

3.3.2. Afridev Hand pump

The Afridev hand pump started life in Malawi in early 1981. From the start, the aim was to produce a deep well hand pump that was very easy to maintain at village level and could be manufactured in countries like Malawi, where industrial resources are limited. The Maldev pump went into production in early 1982, and was a significant step forward in head design, with the users needs given first priority.

Early in the field - testing of Maldev pumps, the ball bearings caused problems and the first Maldev pump head, which uses plastic bearings, was installed in Malawi in late 1982. Major efforts to resolve the bearing problem continued up to early 1985, when a plastic bearing design was finalized.

The focus of Maldev development shifted to Kenya in early 1983 and named Afridev. The pump was developed in Kenya during the course of the UNDP/ world Bank water and sanitation program. The pump is also easy to repair. [5]

The pump stand is a galvanized, all steel fabrication with aT-bar handle to make operation easier. the handle is one set of three length. Hanger and fulcrum bearings are concentric bushes of model engineering plastics which can be hand fitted in the pump head.

The 50mm cylinder is uPVC pipe with stainless steel or brass sleeve. The plunger and footvalve are identical compontents, with molded rubber valve bobbins and nitrile rubber seals.The standard rising main is 63mm OD solvent welded uPVC pipe suspended from the pump stand using a compressed rubber cone. Standard rods are 10mm galvanized or stainless steel with hooked joints that eliminate threads and no need tools for assembly. The research and development has played a vital role in the success of this project , of which the outcome is the Afridev pump system Fig(3-3).

The on going production of afridev can be maintained by villagers men or women after being training in the repair and maintenance.

3.3.3 Atbara Type Hand Pump

This Pump as shown in the figure (3-4) draws water from shallow depths creating a partial vacuum in the suction pipe. Depending on atmospheric pressure to drive water up to the surface, their use is restricted to regions with water tables not more than 8.5 meters below the surface, the pump firstly produced by two mechanics (Mohamed Mahgoub Al Imam & El Guilee El Tom) in Atbara railway workshop during year 1960.(same to the suction pump that was imported from Egypt in past. Then the pump manufactured was transferred to the Atbara industry area by the two mentioned manufactures due to the high demand of the rural communities in a round Atbara and El Damar. Later the pump was modified by Mohamed Mahgoub and his assistance Ibrahim Musa Gabar to reach maximum depth 13 meter by increasing length of the cylinder case (Mohamed Mahgoub, Atbara Industry Area).

Most of all moving parts above ground level are easy to maintain by care taker and villagers. Minor changes like piston rubber, check valve and seat done by pump owner or villagers. All the time the maintenance is carried by the villagers or the pump owner . In the case of major damage parts like cylinder(Wear) or handle bearing or leak of suction water the villagers normally call for a mechanic(manufacture) to repair

3.4 Attempts to Manufacture of India MarkII in Atbara

An attempt to manufacture pump parts for India MarkII was tried in EL Damar by ADS (Area development scheme , UNDP). This first trial was to produce (twenty five) cylinders complete as shown in the figure (3-7).This work was achieved by Saeed Ajamee (Atbara Industrial area) . A cylinder was manufactured from brass complete with the inner parts made from brass, leather and rubber seal with the same dimension to the India II cylinder.The twenty five cylinders were fitted in wells with imported galvanized rising main and connecting rods and pump head assembly . Operation has showed that these cylinders performed efficiently with a disharge rate of 0.31 Lit/stroke compared to imported cylinder which is good of the imported one .

3.5 Type of Hand pumps in the World

The following tables show different types of pumps :-

Table (3-1) High lift Pump (Head ranges from 0-90 Meters)

No.	Pump Type	Country Make	Lifting head (m)	Discharge in (lit/min)	Principle of Operation
01	Abi –ASM	Cote Ivories/France	7-45	10	Diaphragm Type
02	AID deriv, Deep well	Sri lanka	7-45	10-34	Force pump piston type
03	Bestobell	Zambia	7-45	11-12	Force pump piston type Rotary
04	Climax	United kingdom	7-45	8.7-18.5	drive Suction Pump
05	Dragon 2	Japan	7-45	11-22	Force pump
06	Duba tropic 7	Belgium	20-60	17-54	Reciprocating rotary action
07	GSW	Canada	7-45	11.7	Piston type Force Pump
08	India MarkII (Standard)	India, Mali	7-45	12	Piston type Force Pump
09	India MarkII (Modified)	India	7-90	12	Piston type Force Pump
10	Jetmatic deepwell	Philippines	7-45	11-12	Piston type Force Pump
11	Kardia	Germany,Federal.Rep.	7-40	16	Piston type Force Pump
12	Korat	Thailand	7-45	14-16	Piston type Force Pump
13	Monarch P3	Canada	7-45	14-15	Piston type Force Pump
14	Monolift	United kingdom	25-45	9-16	Piston type Force Pump
15	Moyno	Canada	7-45	7-9	Force deep well pump
16	Nira AF84	Finland	7-45	21-23	Positive Displacement pump
17	SWN 80 & 81	Netherland	7-45	5-24	Cavity deep well pump
18	Vergnet	France	7-45	24-28	Deep well force lever arm
19	VEW A18	Austria	7-45	11-30	Reciprocating deep well pump
20	Volanta	Netherlands/Burkina Faso	15-45	15-22	Force pump/rotary mechanism
21	Afridev	Kenya/Malawi	6-45	15-22	Fly wheel rotation reciprocating
22	Consallen	United Kingdom	7-45	14	Deep well r arm force pump

Table (3-2) Intermediate Lift (Head range from 0-25 Meters)

No.	Pump Type	Country Made	Lifting head (m)	Discharge in(lit/Min)	Principle of Operation
01	DMR	Thailand	3-21	20	Reciprocating pump
02	Nira AF76	Finland	7-25	25-26	Lever arm force pump

Table (3-3) Low lift (Head range from 0-12 meters)

No.	Pump Type	Country Made	Lifting	Discharge	Principle of Operation

			head (m)	in(lit/Min)	
01	Blair	Zimbabwe, Malawi/ New Gunina	0-7	24	Direct Action
02	Ethiopia BP50	Ethiopia	7	28	Direct Action
03	IDRC-UM	Malaysia	7-12	25-26	Lever arm force pump
04	Kangaroo	Netherlands	7	10-48	Direct Action
05	Malawi Mark V	Malawi	2-10	36	Direct Action
06	Nira AF85	Finland	7-10	24-26	Direct Action
07	Tara	Bangladesh	7-12	23-24	Direct Action
08	AID suction	Sri lanka	7	29	Direct Action
09	Bandung	Indonesia	7	36	Suction Pump
10	Inalsa suction	India	7	27	Suction pump
11	Jetmatic suction	Philippines	7	24-36	Suction pump
12	Lucky	Thailand	7	24-36	Shallow well Suction Pump
13	New No.6	Bangladesh	7	24-36	Direct Action
14	Rower	Bangladesh	7	27	Direct Action
15	SYB-100	China	7	24-36	Shallow well Suction Pump

3.6 Hand Pump Design Parameters

3.6.1 Pumping Force (F_1)

In positive displacement pump, lifting force that initiates the motion of upper piston upward slightly is equal in magnitude and opposite in direction to the gravitational force affecting connecting rods, piston and water column masses. The pumping force can be estimated as below :-

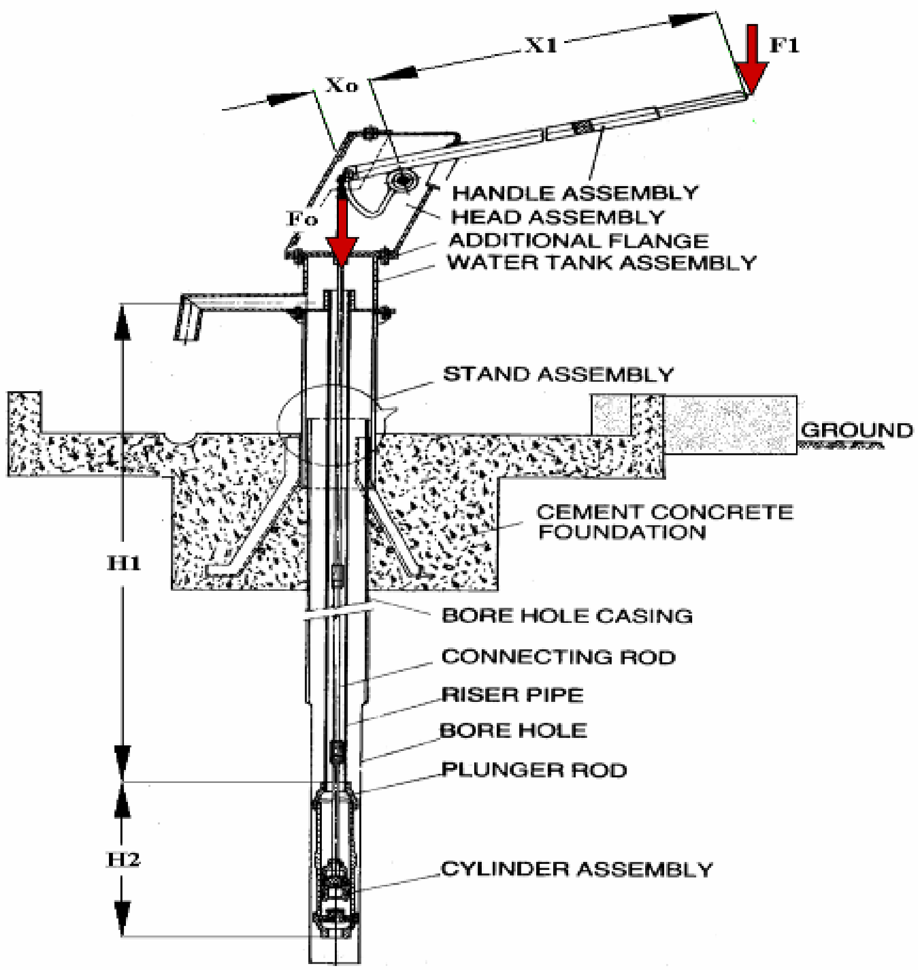


Fig (3-1)

With reference to the figure (3-1), the force is equal to:-

F_1 (Force) = (R.M × g + (W.C1+ $W.C_2$) × g + P.M× g +friction Force) x_o/x_1

Where: -

R.M = Connecting rod mass (kg).

P.M = Piston mass (kg).

W.C_1 = Water Column mass in pipe= $\rho \times A_1 \times H_1$ (kg).

W.C_2 = Water Column mass in cylinder = $\rho \times A_2 \times H_2$ (kg).

A_1: Pipe inner cross section area $(\pi \times D^2{}_1/4 - \pi \times d^2{}_1/4)$ (m^2).

A_2: Cylinder inner cross section area $(\pi \times D^2{}_2/4 - \pi \times d^2{}_1/4)$ (m^2).

H_1: Head of water in pipe (m).

H_2: Head of water in cylinder (m).

D_1: Inner Diameter of Pipe (m).

D_2: Inner Diameter of cylinder (m).

d: Diameter of connect rod (m).

ρ: Density of water ($1000 kg/m^3$)

f: u. PVC or Gal. pipe friction factors.

Xo: Distance from fulcrum pin to rod (m).

X1: Distance from fulcrum pin to end handles (m).

Lifting Force $(F_o) = \{(R.M+P.M+W.C_1+W.C_2+\ell A_1 H_L)\}$ kg.f

Lifting Force $(F_o) = \{(R.M+P.M) + \pi/4 \times \rho \times (D^2{}_1 - d^2) \times (H_1+H_L) + \pi/4 \times \rho \times H_2 (D^2{}_2 - d^2)\}$

Lifting Force $(F_o) = \{(R.M+P.M) + 785.71 \times (1 - d^2/D^2{}_1) \times (H_1+H_L) \times D^2{}_1 + 785.71 \times H_2 (1 - d^2/D^2{}_2) \times D^2{}_2\}$

Where: $d^2/D^2{}_1 < 1$ can be neglect $d^2/D^2{}_2 < 1$ can be neglect

Lifting Force $= \{(R.M+P.M) + 785.71 \times (H_1+H_L) D^2{}_1 + 785.71 \times H_2 \times D^2{}_2\}$ kg.f

Assume: - R.M+P.M = K

Where $H_L = 4fLV^2 / 2gD$ [2].

Then :-

Lifting Force $(F_o) = \{(R.M+P.M) + 785.71 \times (H_1 + 4fLV^2/2gD_1) D^2{}_1 + 785.71 \times H_2 \times D^2{}_2\}$

Lifting Force $(F_o) = \{K + 785.71 \times \{H_1 (D^2{}_1 + 0.33fQ^2/D_1^3) + H_2 \times D^2{}_2\}\}$ kg.f

The apply force by the user to the handle (F_1) equal to

$F_1 = F_o \times x_o/x_1$ where: - x_o/x_1

x_{o}/x_{1} = Handle Ratio (0.122 for India Hand pump, 0.173 for Afridev Hand pump)

Equation No. (1)

$$\text{Applying Force } (F_1) = \{K + 785.71x\{H1\,(D^2_1 + 0.33fQ^2/D_1^3) + H_2 x\, D^2_2\}\} \text{ X } x_o/x1 \quad \text{kg.f}$$

The above mentioned formula can apply to all type of hand pumps.

(f) Can be determining by using two methods:-

First Method:-

f =16/Re for laminar flow, Re less than 2000

f =0.0064/Re $^{0.23}$ for turbulent flow, Re more than 2500

Reynolds Number = νd/υ   ν=Q/A

$$\upsilon = \frac{0.00001929}{1+0.03368t+0.00221t^2} \quad ft^2/Sec \quad \text{(Poiseuille Formula) [10]}$$

Where:-

υ = Kinematics Viscosity

t = Temperature of the borehole water in degrees centigrade

Second Method:-

f =0.2083(100/C)$^{1.85}$xQ $^{1.85}$/Di $^{4.87}$ (Hazen – Williams Formula) [3].

C=constant

Up to 315 mm Dia   C=137-150

Over 315mm Dia   C= 151

3.6.2- Actual Delivery Volume

(V_t) Theoretical delivery Volume = Ap × L   (m^3).

A_p: Means cross-section area of Piston   (m^2).

L: stroke (m).

(V_a) Actual Volume $= V_t \times Eff_{Vol}$ (m^3).

$Eff_{Vol.}$ Volumetric Efficiency.

Where: -

$V_t - Va$ = Slipped volume $=V_S$. (m^3).

3.6.3-<u>Slipped Volume:</u> -

During the movement of the piston upwards, there is a slight delay in closey of the lower piston which causes some of water to escape. Also, for long use of the pump, wear occurs in sealing ring which causes some of the water leakage, this is known as (slipped volume).

Means Eff_{Vol} = Actual Volume /Theoretical Volume

$= V_{a/} V_t$

3.6.4-<u>Actual /Theoretical Pump Power</u>

Theoretical pump power = ℓg Q H ($kg.m^3/ s^2$ $^-$N.m/ s).

Where: -

ρ = Density (1000 kg/m^3).

g = Specific Gravity (9.81 m^2 / s).

Q = Discharge (V_t / time) (m^3/ s).

H = head of water (m).

Where: -

Actual pump power = Eff_{Ov} X ρ g Q H ($kg.m^3/ s^2$ $^-$N.m/ s).

Where

Eff_{Ov}: Overall pump efficiency

3.7- <u>Hand-pumps In Sudan</u>

The implementation of the hand pumps for water supply program in Sudan began in early 1976 in the southern States of the country then the program was substantially expanded by introducing the states of Darfur, Kordofan and the Central provinces. In The Northern of Sudan the hand pumps technology was implemented in 1960 by installing the suction pump that was imported from Egypt. Later Egyptian product manufactured in Atbara industrial area.

Nearly more than sixteen thousand water points equipped with India MarkII, Afridev and Atbara type were installed countrywide. The technology has proved to be essential in providing safe drinking water to the rural communities of the Sudan.

Furthermore, the maintenance system adopted by the water sector concentrated mainly on community participation, Villagers are trained to undertake preventative maintenance and conduct minor repairs

3.8-Community Management of Water point in Sudan

Different methods of the community management applied in both water yards and hand pumps as described below

3.8.1-Community Management of water yards

Since 1970,s when the water yard installations were made, their management has shifted from the central Government to the State Water Corporations, localities and the public committees. Presently, the management of these installations is shared between the States Water Corporations and the public committees. The revenue collected is shared in proportions varying from state to state with Water Corporations and public committee. The revenue that goes to the public committee is supposed to meet the fuel and spare parts expenses while that one, which goes to the State Water Corporation, is supposed to cater for the salaries of the staff deployed in the SWC. Field investigations revealed that cases exist where some public committees do not meet their obligations and the installations are not repaired because of lack of spare parts or do not operate because of lack of fuel.

3.8.2 -<u>Community Management of Hand pumps</u>

Previously the management system undertaken by the RWC staff , with duties including maintenance and operation. But in the introduction of the cost sharing in drilling & erction that introduced by SWC, the management has been in the hands of the communities through the Village Health Committees (VHCs). The VHCs have been supported by the WES units, which are based at the locality level. The VHC members are volunteers appointed by the village public committees, which can appropriately be described as village governments. A WES unit is composed of officers at locality level in the fields of water, health, teaching and community mobilization.

The community management appeared in villages with duties, operation, maintenance and self-management when the government and NGOs stopped supporting maintenance and running operation . This new generation puts the villagers in big responsibilities like water tariff collection, running day to day operation and maintenance during breakdown

In gerneral, the management committee consists of one leader , accountant and five members. with duties supervision, separation of animal human watering, collection of water tariff and maintenance in case of breakdown .

3.9 <u>Operation & Maintenance of the hand pumps</u>:

The old maintenance system consisted of three levels. It was the first institutionalized attempt at involving the users in the maintenance of hand pumps. The system three levels are: -.

First level:-

The voluntary caretaker identified by the implementing agency from among the nearby users. This caretaker is trained for conducting preventive maintenance.

Second level:-

Block mechanic who looks after all the pumps in the block. His duty is to undertake minor repairs.

Third level:-

Mobile maintenance team constitutes the third level and they look after all the hand pumps in the area.

As the years passed, it became evident that the mobile team maintenance system was too expensive. Furthermore, the mobile teams took much time to report to the areas, which required repairs.

The maintenance became very easier when new system developed at Village Level Operation and Maintenance (VLOM) type with new technology Afridev hand pumps

The VOLM type pumps can be operated and maintained by one mechanic with one spanner assisted by one labour

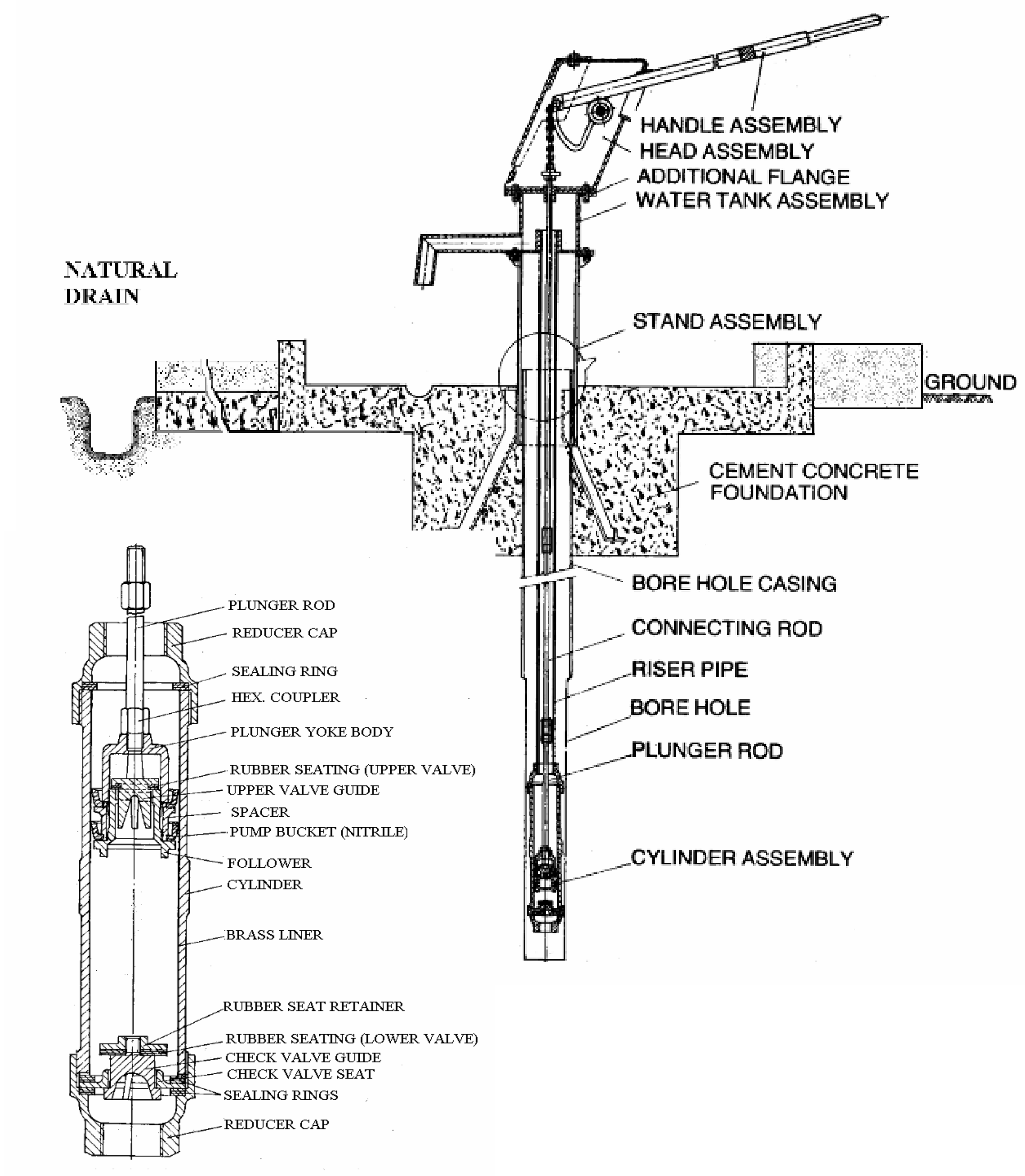
Table (3-4) Hand- Pumps Technical Data

No.	**Data**	**Technical Data for Hand pumps**			
Type of Hand pumps		**Modified India II** (A)	**India II** (A)	**Afridev** (A)	**Atbara type** (B**)**
01	Maximum setting depth in (m)	90	45.00	45.00	8.5
02	Minimum borehole diameter in (mm)	100	100	100	100
03	Maximum borehole in (mm)	150	150	200	150
04	Cylinder diameter in (mm)	63.5	63.5	63	127
05	Stroke length in (mm)	100	125	225	600
06	Discharge in liters per stroke	0.375	0.375	0.4125	0.5
07	Raising main diameter in (mm)	32	32	63	50.8
08	Pump rod diameter in (mm)	12	12	10	12

Note:
A: Theroritical data collected from KARNATAHKA water pumps sheet ref. (http:// www.pps.india.com) Merra Seeka Corp.
B: Data collected by the writer and team from ADS El Damar.

Table (3-5) Hand pumps Parts Material

No	Pump items	Pump Materials		
		India II	**Afridev**	**Atbara**
01	Head assembly	Mild steel Fabrication Construction, mild Steel conforms to IS: 2062. Hot dip galvanized front cover mild steel IS: 2062	Steel welded fabrication hot dipped galvanized St 37 DIN 2458-DIN59411	Steel pipe
02	Handle assembly	Mild steel Fabrication handle bar conforms IS: 2062	T. Bar steel made St37 DIN 2458-	Mild steel
03	Water Tank	Mild steel Fabrication of welded Construction. Tank Pipe and spout Conforms IS: 1239 Riser pipe holder And flange Conforms IS: 2062	Mild steel pipe connect to pedestal	Steel pipe dia 5 inch
04	Stand assembly	Mild steel Fabrication of welded stand pipe IS: 1239-pipe IS1161 legs Conforms IS2062	Steel fabrication welded pipe St 37	Steel stand
05	Raising main	Galvanized steel pipe 1.25 inch Dia	uPVC pipe 2 inch, 15 bar	Galvanized pipe 2 inch
06	Connect rod	Mild steel rods and stainless steel rod conform IS: 1573	Mild steel rod	Mild steel
07	Cylinder	Material for Cylinder body IS 210 brass liner IS: 407 nitrite Rubber component IS: 3020	50mmID X 700 mm stainless steel tube	Steel pipe 5 inch dial
08	Upper valve	Brass-rubber	Polyacetal plastic rubber	Mild steel and rubber
09	Lower valve	Brass-rubber	Polyacetal plastic rubber	Steel and rubber



INDIA MARKII CYLINDER ASSEMBLY

Fig (3-2) India Mark II Hand pump

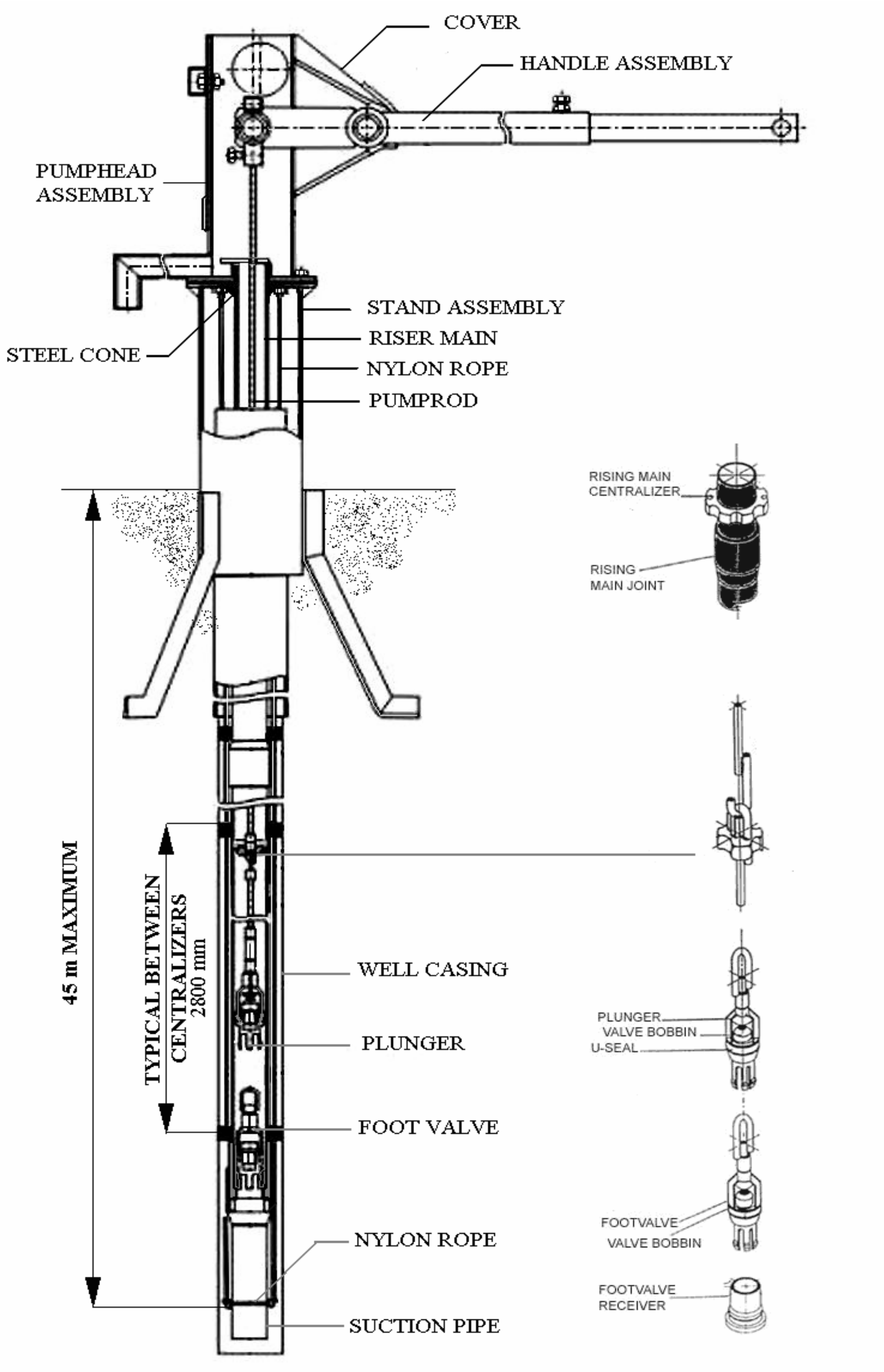
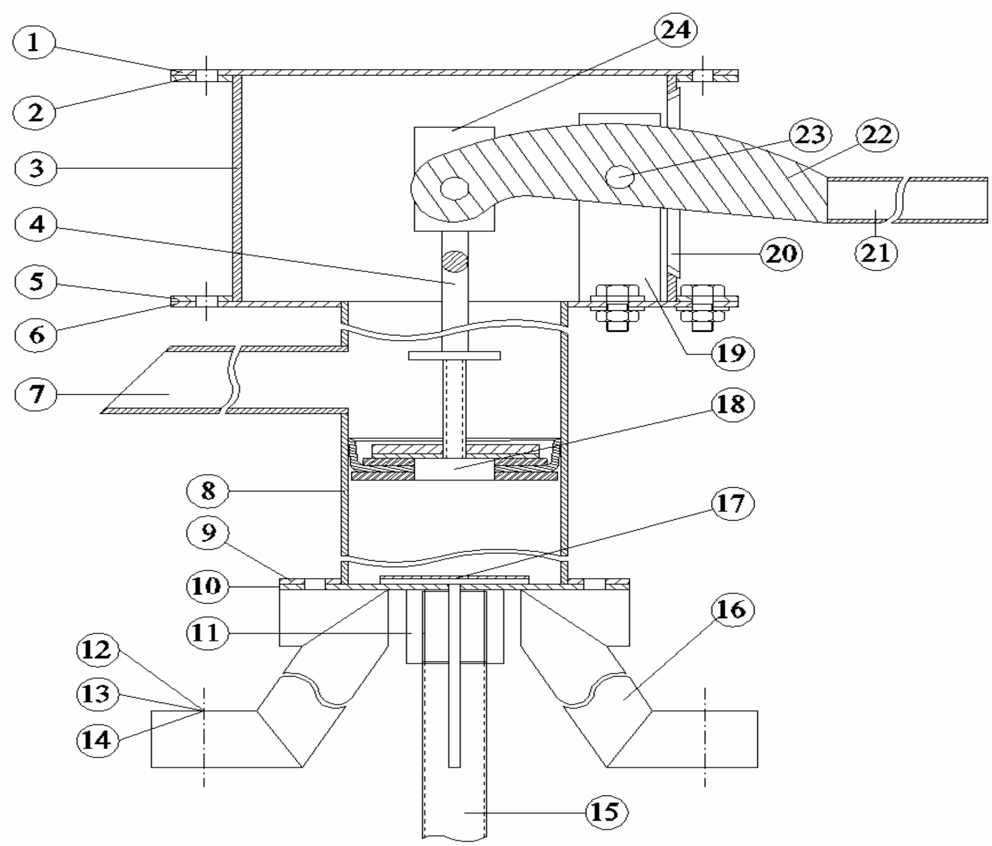


Fig (3-3) Afridev Hand pump



NO	PART NAME	No Off	MATERIAL	No	PART NAME	No Off	MATERIAL
1	HEAD COVER	1	MILD ST.	13	FOUNDATION NUT	4	STEEL
2	HEAD COVER TOP FLANGE	1	MILD ST.	14	FOUNDATION WASHER	4	STEEL
3	HEAD COVER CYLINDER	1	MILD ST.	15	RISER PIPE	3	GALVE ST.
4	PLUNGER ROD	1	MILD ST.	16	LEG	4	ANGLE ST.
5	HEAD COVER BOTTOM FLANGE	1	MILD ST.	17	FOOT VALVE ASSY.		
6	CYLINDER TOP FLANGE	1	MILD ST.	18	PISTON ASSY.		
7	SPOUT	1	GALV. ST.	19	AXLE HOLDER BRACKET	1	MILD ST.
8	PUMP CYLINDER	1	GALVE ST.	20	BRACKET	1	MILD ST.
9	CYLINDER BOTTOM FLANGE	1	MILD ST.	21	HANDLE BAR	1	GALV. PIPE
10	RISER PIPE FLANGE	1	MILD ST.	22	HANDLE HEAD	1	FORGED ST.
11	RISER PIPE HOLDER	1	GALV ST.	23	AXLE 15 M X 2P (BOLT,NUT,WASHER)	1	STEEL
12	FOUNDATION BOLT M14 x 2P	4	STEEL	24	PLUNGER ROD HOLDER BRACKET	1	MILD ST.

Fig (3-4) Atbara Type Hand pump

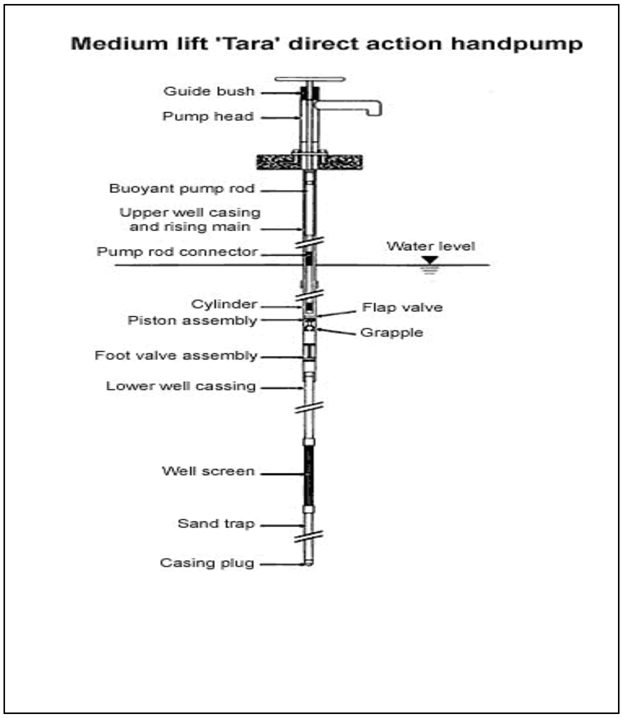


Fig (3-5) Direct Action Hand pump

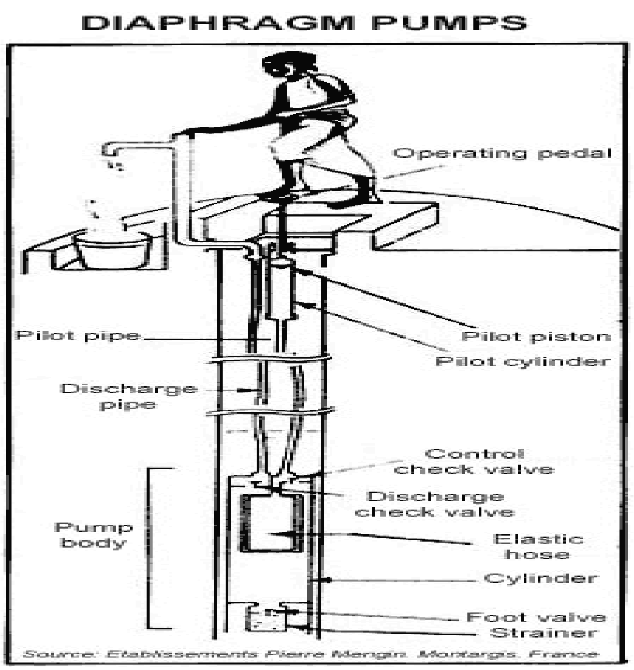


Fig (3-6) Diaphragm Pump

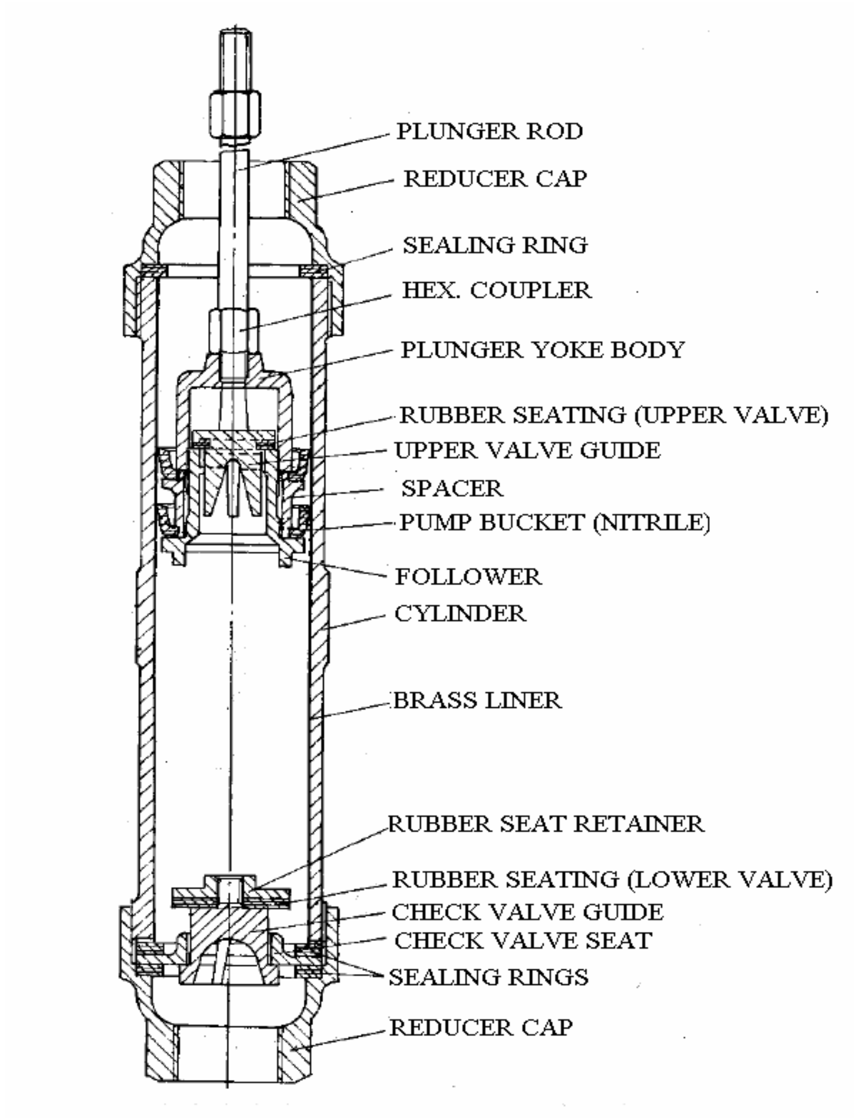


Fig (3-7) Local Production cylinder for India MarkII Hand Pump

Chapter IV

CHAPTER FOUR

DATA COLLECTION

4.1 Introduction

The last evaluation report achieved by water project officers at WES sectors, NWC and SWC in Sudan at states showed that a number of hand-pumps are out of order in Kordofan, Darfur, Southern, Northern and Eastern Sector as shown in the table (4-1).

It was observed from table(4-1),that more hand-pumps out of order concentrated at Northern Kordofan, Northern Darfur and Juba. With percentage of 42.4%,34.3% and 42.3% respectivelly and Nahr Al-Niel State 25%.

Survey was conducted to produce considerable new evidences that will lead to cover the factors which assisted in the decline of the hand-pumps performance and reliability in Sudan. The survey started in mid of March .2000 up to July .2000 for the collection of data.

4.2 Procedure and material used for the Study

The following are the tools used to obtain useful information related to hand pumps water supply and community management& maintenance system at village level:-

a/ Management of the Hand-pump

For the management of the hand-pumps in the village the following procedure was implemented to collect the data from villagers, Local authorities and base village committees:-

1. The team contacted local authorities and community based organizations for introduction to the village leaders and other local authorities to explain the purpose of the visit.
2. Interview some of the beneficiaries and some of the pump users about the amount of water consumed per day for the human being and animals.
3. Discussion with village committees and beneficiaries about the method of water tariff collection and the problem related to the management of the water system.
4. Study the elements related to water management one by one by asking the beneficiaries about the strengths/weaknesses or threats related to the topic. Then discuss with them how to avoid or deal with the weaknesses.

b/ Hand- pump Borehole Data

The borehole data collected from the field work by using testing instruments at each borehole equipped with hand-pump. And the data collected are:-

Water pH, Discharge, borehole water temperature, pumping setting depth, hand pump type, location of the site and breakdown frequency with parts consumed per year.

c/ Data from SWC/WES Offices

The data collected from SWC/WES offices at Northern Kordofan, Northern Darfur, Juba and El Damar was static water level, pump setting depth, water quality and cost of hand pump parts that are not available at site attached the questioners Fig (4-1).

Table(4-1) <u>Hand pumps Distributed Round Sudan</u>
Monitoring Survey. (Jan. 2000)

#	Region	State	Total Handpump	Functioning			Not-functioning				Percentage of Fun, Unfun.		Ref.
*				**India MKII**	**Afridev**	**Atabra Type**		**India MKII**	**Afridev**	**Atabra Type**	**Function.**	**Not-function**	
1	Darfur	S. Darfur	689	423	30			226	10		65.75%	34.25%	A+B
2	Darfur	W. Darfur	629	542	1			85	01		86.3%	13.7%	A+B
3	Darfur	N. Darfur	1067	644	57			330	36		65.7%	34.3%	A+B
4	Kordofan	S. Kordofan	4000	3296	254			447	03		88.75%	11.25%	A+B
5	Kordofan	N. Kordofan	2760	1570	20			1155	15		57.6%	42.4%	A+B
6	Kordofan	W. Kordofan	1248	916	20			302	10		75%	25%	A+B
7	Khartoum	Khartoum	847	734	18			95	0		88.79%	11.21%	A+B
8	Central	Sennar	1928	1695	40			186	7		90%	10%	A+B
9	Central	W. Nile	433	293	32			108	0		75%	25%	A+B
10	Central	B. Nile	290	148	70			67	5		75.2%	24.8%	A+B
11	Central	Gezira	159	31	88			30	10		74.8%	25.2%	A+B
12	Eastern	Gadarif	76	37	20			14	05		75%	25%	A
13	Eastern	Kassala	**8**	**7**	-			1	-		87.5%	12.5%	A
14	Bahar ElGazal	N. Bahar ElGazal	107	100				7			93.5%	6.5%	A
15	Bahar ElGazal	W. Bahar ElGazal	640	500				140			78.2%	21.8%	A
16	Equatoria	East Equatoria	116	97				19			83.6%	16.4%	A
17	Equatoria	Bahar Al Gabal	496	286				210			57.7%	42.3%	A+B
18	Upper Nile	Unity	30	23				7			76.7%	23.3%	A
19	Upper Nile	Malakal	70	53				17			75.7%	24.3%	A
20	Nile State	Atbara/El Damar/Shinda	502	76		300		25	01	100	74.9%	25.1%	**B**
21	Eastern	Sinkat/Dordab	93	73				20			78.5%	21.5%	C
Total Handpumps			**16188**	**11544**	**650**	**300**		**3491**	**103**	**100**			

Note (Ref.):- **A:** Means Data collected from WES UNICEF annual report 1999 (Khartoum WES Office) by the writer
B: Means data collected from states /province by the writer and the monitoring section at WES project at Jan./2000 .
In Damar / Atabra/ Shinda data collected from ADS office , writer and rural water staff.
C: Data collected from Eastern Sector Proposal plan of Action. By the writer

Hand Pump and Community management Profile Form

STATE : ______________________________

PROVINCE/LOCALITY: ______________________________

AREA: ______________________________

VILLAGE : ______________________________

S E C T O R ______________________________

Geographical Background

Geographical location of the study area (longitudes and latitudes)		
Geographical location of the area from near towns & villages in time and distances		
Distance in time	Distance in Kilometers	Area name
Other remarks		

Population Information

Total population	
Number of families	
Number of households	

Daily of water consumption per day per person in lit

Season	Water for Drinking	Water for cleaning	Water for cooking	Water for other
Autumn				
Winter				
Summer				

Livestock consumption per day in lit

Live Stocks	Goats	Sheep's	Cows	Donkeys	Camels	Other
Number						
QTY of Water drinking /Day						

Water sources / Hand pump

		General Information of the Hand Pump							
Type of water source	Type of Hand Pump	Water temperature	Water pH	Discharge in lit/stroke	Discharge in lit/sec	Pump Type	P/D	SWL.	Borehole Depth.

Water sources / Other

Type of water source	. No.	General Information
Water Yards		
Dams		
Water pool		

Management of Water points

Village committee:-

Committee member			Village committee	
Name	Job in committee.	Responsibility	No of person in committee.	Type

Water tariff collection type, mode and utilize	**Sale centre spare part price**

Other issue related to the Management

Maintenance frequency table per year per pump

Spare Part consumed per year per pump for both India and Afridev									Maintenance per year.
Rising main	Cylinder	Plunger Yoke	Connecting rod	Chain	Handle bearing	Seal ring	Check valve.	Other.	

Fig (4-1) Questioner for hand pumps and community management

4.3 Study of Water Parameters in the filed

The water parameters that are studied in the field are:-

4.3.1 Temperature:

The temperature of the ground water samples was measued immediately as soon as the samples were taken. The results showed a water temperature variation between 23.6 ^{0}C to 36.5 ^{0}C

4.3.2Hydrogen-ion concentration (pH):

The relative concentration of hydrogen ions in water indicates whether the water will act like weak acid or as alkaline solution depending on the relative concentration of hydrogen ions in water [22].

The hydrogen ion concentration in water is expressed in terms of pH. The pH is equal to the logarithm of the inverse of the hydrogen ion concentration or: $pH= Log\ 1/H^+$ [15].

The pH range from 0 up to 14 , with pH valve of 7 at (25 ^{0}C) indicating a neutral solution in which H^+ and OH^- ions have the same concentration A pH less than 7 indicates an acid solution, whereas a pH greater than 7 indicates an alkaline soultion.

The pH of the water samples was measured in the field immediately by pH-meter equipped with two electrode with accuracy of 0.01 to 0.05 pH. The groundwater in the study area has pH valves ranging from 6.0 up to 7.3.Tables(4-2,4-3,4-4 and 4-5).

4.3.3 Static Water Level:

This is a level at which water stands in a well when no water is being taken from the aquifer either by pumping or by free flow . It is generally expressed on the distance from the ground surface to the water level in the well [22].

The static water level for 29 boreholes taken from water department at each state, as shown in the tables (4-2,4-2,4-4 and 4-5).

4.3.4 Pump setting depth :

The pump setting depth for 29 boreholes were taken from water sector at each states, tables(4-2,4-2,4-4 and 4-5).

4.3.5 Well Yield or Discharge:

Measured by using reservoir capacity four gallons and stop watch for all the 29 wells at the site.

4.4Criteria for site Selection

Good Quality of groundwater

Public undertake responsibility of management

Community members willing to cooperate and to develop their communities

Caretaker recordering the breakdowns

4.5Selected Site for Research

The sites selected for field testing are in the following regions:

4.5.1 Darfur Region

Northern Darfur State – Inside and south of El Fashir about 60 Km distance – Data in tables (4-4,4-4i,4-4ii).

4.5.2 Kordofan Region

Northern Kordofan State – North and East El Obied about 40 KM distance – Data in tables (4-2,4-2i,4-2ii).

4.5.3 South Sudan Region

Bahr El Jabal State – Juba (Locality of Muniki and Locality of Atla Bara) as Shown in data tables (4-4, 4-4i).

4.5.4 Nahr Al-Niel state

El Damar / Atbara- ADS workshop, data in tables (4-5, 4-5i).

4.6 Selected Pumps for test

The pumps selected for test are in the following areas:

Pump Type	**Selected Area**	**QTY**
India Mark II	N. Kordofan / Darfur / Juba	20
Afridev	N. Kordofan / Darfur	8

Atbara Type	Nile State	3
Local Manuf. India MarkII	El Damar	1

4.7 <u>Community Participation in Management</u>

The states water coorporation joint with WES projects and NWC had applied different methods of manangement in different areas as mentioned in the selected study areas.

Underneath are case studies for community management, operation and water tarriff collection in Northern Darfur (El Fasher), Northern Kordofan and Southern Sudan (Juba).

4.7.1 <u>Case Study in Northern Kordofan (El Ayara)</u>

This assessment undertaken first by teams including representative from UNICEF WES office(Vishaws) Manager of Meera / Ceika India company for production of hand-pumps (Mr. Desisa), Dr. Mudawi Ibrahim Adam and my-self to study the hand-pump management system and breakdown frequency at El Ayara village .

Second assessment undertaken by the Northern Kordofan WES project monitoring officer, a geologist from SWC and my-self to study breakdown frequency for ten pumps in Northern Kordofan as shown in tables (4-2,4-2i and 4-2ii).

El Ayara	20 Km West of El Obied
Total population	1500 Persons
Total No. of hand pumps	two
Type of hand pumps	India MarkII

<u>Hand-pumps Working hours</u>

In dry season	18 hours
In winter season	10 hours

Quantity of water produced by hand-pumps and water Demand.

(El Ayara Village)

No. of hand pumps x working hoursx quantity produced / hour

Qty of water Produced by pump per-day

2 PumpsX18 working hoursX0.27 lit/ secX60X60 = 7776 Gallons/Day

Total out-put = 7776 Gallons/Day

(0.27 lit/sec table (4-2)).

The Demand in summer:

For The Human being:-

No. of Human being x Average need per person per day

1500 X23lit = 7666.6 Gallons/day Table(4-6)

For The Live-stock:-

For lives stock = 557.30 Gallons/day Table(4-6i)

Total quantity required = 8223.96 Gallons/day

Quantity produced by hand pumps is 94.5**%** of the total needs of both human and livestock .

The deficit is 447.96 Gallons /day.In the dry season the two hand-pumps should work 20 hours to satify the water requirement.

The management of the hand-pumps carried out by the health committee, which consists of five persons as stated below:-

1-Committee leader

2-Accountant

3-Three committee members

The Committee Undertakes the following Duties : -

-Collecting water tariff from people of the village at the cost of (18 lit =50 SD).The collection money saved in village box (3000 SD of saved money paid to the WES Project Office in each month).

-Maintenance of hand pumps in case of breakdown by providing spare parts and fees for the pump mechanics.

-Closing the entire hand pumps in the rainy season. And let the villages get their water from the Haffir and organize the livestock/human- being watering during dry months

- All the hand pumps mechanics trained to do the maintenance left the village. That means in the case of breakdown they have to search for pump mechanics to carry out maintenance.

During the field visited, it was observed that VHCs were very weak or has disintegrated altogether in some villages. Most WES units were observed to only exist by name, as they do not support the VHCs in that manner. The State Water Authorities at the provincial level on the other hand have dropped out from their agenda the monitoring of the hand pumps operations and maintenance. Interviews with some members of the WES units and Rural Water Corporations confirmed this observation. WES units attributed this situation to lack of support from the localities.

Due to the vastness of the states and inadequate logistical support, the WES projects at state level that are supposed to monitor the operations at the WES units are not able to do so effectively. This has led to a situation where the management of hand pumps is either inadequate or absent altogether resulting in lack of tariff collection systems and breakdowns.

Another case of community management in Southern Sudan (Juba)

4.7.2Case study in Juba (Southern Sudan)

This assessment was undertaken by the WES monitoring officer at Juba, two persons from health committee, drilling supervisor and myself to study the six India MarkII selected among the 98. The pump data and frequency of breakdown are given at tables (4-3,4-3i).

Locality Muniki	West Juba city
Total population	5663 Persons

Total number of hand pumps	98
Functioning hand pumps	31
Type of hand pumps	India MarkII

Working hours of the pumps:

In dry season	10 hours
In rainy season	6 hours
In winter season	8 hours

Quantity of water produced by hand pumps (Mahlia Muniki)

No.of hand pumps × working hours × Quantity produced/ hour

= 31X10X0.252X60X60 =62496 Gallons/day

(0.252 lit/sec. table (4-3).

For human being

No. of Human being × Average need per person =5663X22lit =

=27685.7 Gallons/day Table (4-7)

For livestock = 1733.33 Gallons/day Table (4-7i)

Quantity of water required per day for livestock +Quantity of water required per day for human being (1733.33+27685.7) = 29419.10 Gallons/day

(if all the 31pumps are working means the access to safe water is 33076.9 Gallons/day).

The management of water point (hand pumps) is the responsibility of the health committee that are selected from communities or villagers, consisted of five women and five men as stated here under:

The leader of the committee	One Person
Leader assistant	One person
Secretary	Two Persons

Accountant	One Person
Members	Five Persons

The Responsibilities of Committee

-Collecting of water tariff from population (two tin cost 50SD). The committee pays (5000 SD) monthly to the WES water project that drilled the borehole and installed the hand pumps. The balance saved in committee box. Mr. Kaden Kuyu said that the amount of money gathering is very small. This a result of that all churches, schools and mosques are watering free from the hand pumps adjacent to them. Also the beneficiaries are unwilling to pay

-During the breakdown the health committee should inform the WES project officer to give free repair parts

-Health committee should keep area round the hand pumps clean at all time.

4.7.3 Case study in Northern Darfur

This assessment was undertaken by a team consisted of WES monitoring officer, leader of installation team, one of the WES unit at Locality Abu Zrake and my-self, to study the performance, management procedures and breakdown frequency. The study included four hand pumps in El Fasher area. Tables (4-4, 4-4i and 4-4ii).

Site: - Abu Zrake 60-Kilo South from El Fasher

Total population	6000 Persons

Water Resources in the village

Capture Pool	One Pool	
Hand pumps	Six Hand pumps	
Type of hand pumps	Afridev /India	Table (4-4)
No. of Functioning Hand pumps	Five (2India MarkIIs, 3 Afridevs)	

Hand Pumps working hours

In dry season	18 hours

In winter season 10 hours

Five villages watering from five pumps in dry ,winter seasons

At rainy season all the villagers watering from the capture pool .

Quantity of water produced by hand-pumps and water Demand.

(Abu Zrake Village)

No. of hand pumps x working hoursx quantity produced / hour

Qty of water Produced by hand-pumps per-day

4 PumpsX18 working hoursX0.29 lit/ secX60X60	=	16704Gallons/Day
2 Pumps X18 working X0.285lit/sec X60X60	=	8208 Gallons/Day
Total out put	=	24912 Gallons/Day

(0.29 lit/sec, 0.285 lit/sec. table (4-4)).

The Demand in summer:

No. of Persons x Average need per person per day

6000X22lit	=29333.3 Gallons/day Table(4-8)
For live stock	=11000.00 Gallons/day Table(4-8i)
Total quantity required	= 40333.3 Gallons/day

Quantity produced by hand pumps is **<u>61.7%</u>** of the total needs of both human and live-stock .

The deficit is 15421.3 Gallons /day.To cover the need, another four boreholes need to be drilled and hand-pumps installed.

The managment of the hand-pumps carried out by the health committee, which consists of seven members organized in the following manner :-

1-Committee leader

2-One accoutant

3-Five committee members

The committee undertake the following duties : -

-Gathering water tariff from people of village (the cost of two tin 36 lit = 50 SD) collected and saved in village box.

-Maintenance of hand pumps in case of breakdown by providing the spare parts from town and fees for the hand pumps mechanics.

-Closing the entire hand pumps in the rainy season. And let the villagers get their water from the water pool.

-Organize the livestock/human being watering during dry months.

4.7.4 Case study in El Damar/ Atbara

This assessment was undertaken by a team consisted of SWC Atbara officer, WES project officer at El Damar and my-self to study the performance of the local manufacturing India MarkII cylinder and the breakdown part of Atbara type pump Tables (4-5, 4-5i).

The attempt to manufacture pump parts for India MarkII was tried in El Damar by ADS and UNDP. This first trial produced (twenty five) cylinder complete.This work was achieved by Saeed Ajamee (Atbara Industrial area). A cylinder was manufactured from brass complete, leather and rubber seal with same dimension to the India markII cylinder.The twenty five cylinders were fitted in wells with imported galvanized rising main and connecting rods and pump head assembly. Operation has shown that these cylinders performed efficiently with a disharge rate of 0.31 Lit/stroke compared to the imported cylinder. tables (4-5,4-5i)

Table (4-2)

Data collected from Northern Kordofan State
Hand pumps – General information

Province / District	Site Location	Lat.	Long.	Total Depth (Borehole) (m)	SWL (m)	P/D (m)	Pump type	Discharge Liter/sec	Discharge Liter/stroke	Water Temp (C^0)	Water Ph	Pump Management	Total of population (Persons)	User preferable
Sheikan	El Hmadia 1	$13^0\ 12'\ 20''$	$30^0\ 25'\ 22''$	58.00	40.00	48.00	India Mark II	0.24	0.29	28.2	7.0	Community	2000	India MII
Sheikan	El Hmadia 2	$13^0\ 12'\ 23''$	$30^0\ 25'\ 24''$	58.00	40.00	48.00	India Mark II	0.24	0.31	29.5	7.1	Community		India MII
Sheikan	Um Ashira3	$13^0\ 23'\ 50''$	$30^0\ 19'\ 20''$	69.00	50.00	62.00	India Mark II	0.24	0.30	32.6	6.0	Community	3000	India MII
Sheikan	Um Ashira4	$13^0\ 23'\ 55''$	$30^0\ 19'\ 22''$	69.00	54.00	60.00	India Mark II	0.27	0.32	29.4	6.2	Community		India MII
Sheikan	Um Ashira5	$13^0\ 23'\ 40''$	$30^0\ 19'\ 35''$	63.00	36.00	55.00	India Mark II	0.24	0.33	32.2	6.9	Community		India MII
Sheikan	El Ayara	$13^0\ 9'\ 30''$	$30^0\ 5'\ 30''$	75.00	40.00	60.00	India Mark II	0.28	0.34	34.2	7.0	Community	1500	India MII
Sheikan	El Ayara	$13^0\ 9'\ 35''$	$30^0\ 5'\ 32''$	75.00	46.00	62.00	India Mark II	0.26	0.30	28.4	7.0	Community		India MII
Sheikan	Abu Khress	$13^0\ 16'\ 40''$	$30^0\ 12'\ 15''$	51.00	36.00	48.00	Afridev	0.31	0.39	29.6	7.1	Community	500	India MII
Sheikan	El Donkg	$13^0\ 28'$	$30^0\ 20'\ 25''$	78.00	51.00	66.00	Afridev	0.27	0.38	33.4	6.9	Community	1200	India MII
Sheikan	El Donkg	$13^0\ 28'\ 28''$	$30^0\ 20'\ 30''$	75.00	51.00	66.00	Afridev	0.31	0.38	33.2	6.5	Community		India MII
Sheikan	Hilat Abass	$13^0\ 2'\ 45''$	$30^0\ 10'\ 15''$	54.00	33.00	44.00	Afridev	0.31	0.38	28.6	7.0	Community	1500	India MII

Table(4-3)
Data collected from Bahr El Jabal state
Hand pumps – General information

Province / District	Site Location	Lat.	Long.	Total Depth (Borehole) (m)	SWL (m)	P/D (m)	Pump type	Discharge Liter/Sec	Discharge Liter/stroke	Water Temp (C^0)	Water Ph	Pump Management	Total of population (Persons)	User preferable
Juba	Monica A	**$4^0\ 50'\ 12''$**	**$31^0\ 30'\ 10''$**	33.00	18.00	24.00	India Mark II	0.26	0.32	28.2	7.0	Community	5663	India MarkII
Juba	Monica B	**$4^0\ 50'\ 11''$**	**$31^0\ 30'\ 9''$**	33.00	18.00	22.00	India Mark II	0.27	0.33	28.5	6.9	Community		India Mark II
Juba	Monica C	**$4^0\ 50'\ 14''$**	**$31^0\ 30'\ 12''$**	30.00	18.00	24.00	India Mark II	0.23	0.29	27.6	7.0	Community		India Mark II
Juba	Monica D	**$4^0\ 50'\ 10''$**	**$31^0\ 30'\ 8''$**	30.00	18.00	25.00	India Mark II	0.25	0.31	27.6	7.1	Community		India Mark II
Juba	SFM Workshop	**$4^0\ 50'\ 8''$**	**$31^0\ 30'\ 6''$**	28.00	18.00	23.00	India Mark II	0.24	0.29	27.4	6.8	Community	200	India Mark II
Juba	Atla Bara	**$4^0\ 50'\ 9''$**	**$31^0\ 30'\ 9''$**	21.00	12.00	18.00	India Mark II	0.23	0.28	23.6	6.9	Community	1200	India Mark II

Table (4-4)
Data collected from Northern Darfur state
Hand pumps – General information

Province / District	Site	Long.	Lat.	Total Depth (m)	SWL (m)	P/D (m)	Pump type	Discharge Litre/Sec	Discharge Litre/stroke	Water temp (C^0)	Water Ph	Pump Management	Total of population Persons)	User Preferable
EL FASHIR NORTH	ABU SHOOK 1	$13^0\ 36^/\ 57^{"}$	$30^0\ 25^/\ 22^{"}$	60.00	24.00	54.00	India Mark II	0.23	0.26	36.4	7.3	Community	1500	India MII
EL FASHIR NORTH	ABU SHOOK 2	$13^0\ 36^/\ 17^{"}$	$30^0\ 25^/\ 24^{"}$	72.00	36.00	64.00	India Mark II	0.18	0.20	35.4	7.0	Community		India MII
EL FASHIR NORTH	(Al Rab Al wail)	$13^0\ 33^/\ 01^{"}$	$30^0\ 19^/\ 22^{"}$	45.00	20.00	30.00	India Mark II	0.21	0.25	28.6	6.5	Community	540	India MII
EL FASHIR NORTH	(Al Rab Al wail)	$13^0\ 33^/\ 10^{"}$	$30^0\ 19^/\ 35^{"}$	45.00	20.00	30.00	India Mark II	0.12	0.16	29.6	6.5	Community		India MII
DAR EL SALAM	ABU ZRAK	$13^0\ 30^/\ 50^{"}$	$30^0\ 5^/\ 30^{"}$	45.00	23.00	39.00	India Mark II	0.29	0.29	27.0	7.1	Community	6000	India MII
DAR EL SALAM	ABU ZRAK	$13^0\ 30^/\ 58^{"}$	$30^0\ 5^/\ 32^{"}$	42.00	23.00	39.00	India Mark II	0.28	0.30	28.8	7.2	Community		India MII
DAR EL SALAM	ABU ZRAK	$13^0\ 30^/\ 57^{"}$	$30^0\ 12^/\ 15^{"}$	48.00	28.00	45.00	Afridev	0.29	0.35	28.5	7.0	Community		India MII
DAR EL SALAM	ABU ZRAK	$13^0\ 28^/$	$30^0\ 20^/\ 25^{"}$	51.00	31.00	48.00	Afridev	0.30	0.34	31.4	7.1	Community		Afridev
DAR EL SALAM	ABU ZRAK	$13^0\ 12^/\ 20^{"}$	$30^0\ 25^/\ 22^{"}$	48.00	30.00	45.00	Afridev	0.31	0.36	28.6	7.0	Community		Afridev
DAR EL SALAM	ABU ZRAK	$13^0\ 12^/\ 23^{"}$	$30^0\ 25^/\ 24^{"}$	45.00	27.00	42.00	Afridev	0.26	0.32	27.8	6.7	Community		Afridev

Table (4-5)

Data collected from Local Manufacture Of Hand pump Cylinder
Nahr Al- Neil State
Hand pumps – General Formation

Province / District	Site	Long.	Lat.	Total Depth (Borehole) (m)	SWL (m)	P/D (m)	Pump type	Discharge Liter/Sec	Discharge Liter/stroke	Water Ph	Pump Management	Total of population (Persons)	User preferable
Al Damar	ADS Workshop	$33^0\ 57^/\ 20^{"}$	$17^0\ 35^/\ 3^{"}$	15	11	13	India Mark II	0.24	0.31	6.50	Community	25	India Mark II

Table (4-5i)
Data collected from Local Manufacture Of (India Mark II Hand pump Cylinder)
Nahr Al- Neil State
Maintenance Frequency Table Per Year – Per Pump

A:- INDIA MAKII HANDPUMP TYPE

Site	**Chain/w coupling**	**Handle bearing**	**Water Tank**	**Plunger Rod**	**Sealing Ring**	**Plunger Yoke Body**	**Rubber Seating Small**	**Upper Valve**	**Pump Bucket**	**Rubber seating big**	**Connecting Rod**	**Check Valve**	**Riser pipe**	**Pump Condition**	**Maintenance Frequency No./ Year**	**Spare part access**	**Maintenance Cost (SD)**	
																	Lab. C	Spare . C
ADS Workshop									2					Fair	2/1		2000	1000

Table(4-2i)
Data collected from Northern Kordofan state
Maintenance Frequency Table per Year – Per Pump

A:- INDIA MAKII HANDPUMP TYPE

Site	**Chain/w coupling**	**Handle bearing**	**Water Tank**	**Plunger Rod**	**Sealing Ring**	**Plunger Yoke Body**	**Rubber Seating small**	**Upper Valve**	**Pump Bucket**	**Rubber seating big**	**Check Valve**	**Conrod**	**Riser Pipe**	**Pump Condition**	**Maintenance Frequency No./ Year**	**Spare part access**	**Maintenance Cost (SD)**	
																	Lab. C	Spare. C
El Hmadia 1									2		6	1	2	Fair	5/5	No.	15000	25500
El Hmadia 2		2			3									Fair	2/5	No.	6000	8000
Um Ashira3	2						2		4			2	2	Bad	8/4	No.	24000	31200
Um Ashira4		2					2	2	4			3	4	Fair	4/4	No.	12000	39200
Um Ashira5									3			3	3	Fair	5/4	No.	15000	20500
El Ayara					4			2	8		1	1	1	Bad	11/6	No.	55000	44500
El Ayara					3				6		2	1	1	Bad	10/6	No.	50000	46000

Table (4-2ii)
B:- AFRIDEV HANDPUMP TYPE

Site	**Pump Condition**	**Spare part accessible**	**H. F.P**	**Bush bearing**	**Rod hanger assy**	**Pin sleeve**	**Rod**		**Plunger valve**	**U- Seal**	**O- Ring**		**Pipe**		**Valve**		**Maintenance Frequency No./ Year**	**Maintenance Cost (SD)**	
							Con.	**Cent**			**Foot**	**Rec.**	**Cent**	**uPVC**	**Foot**	**Bobbin**		Lab. C	Spare .C
Abu Khress	Fair	No.												2			2/1	6000	7000
El Donkg	Fair	No.												2			2/1	6000	8000
El Donkg	Fair	No.													1		1/1	3000	2000
Hilat Abass	Fair	No.												1			1/1	3000	3200

Table (4-3i)
Data collected from Bahr El Jabal state
Maintenance Frequency Table per year – Per Pump

A:- INDIA MAKII TYPE

Site	**Chain**	**Handle bearing**	Water Tank Washer & nut	Plunger Rod	**Sealing Ring**	**Plunger Yoke Body**	**Rubber Seating small**	**Upper Valve**	**Pump Bucket**	**Rubber seating big**	**Check Valve**	**Connecting Rod**	**Riser Pipe**	**Pump Condition**	**Maintence No./year**	**Spare Part Accessible**	**Maintenance Cost (SD)**	
																	Lab. C	Spare .C
MONICA A		1			1		1		1		1			Fair	3/1	No.	PWO	FWP
MONICA B									1					Fair	2/1	No.	PWO	FWP
MONICA C								1						Fair	1/1	No.	PWO	FWP
MONICA D									1		1			Fair	1/1	No.	PWO	FWP
SFM WORK-SHOP		1							1					Fair	2/1	No.	PWO	FWP
ATL BARA		1							1					Fair	2/1	No.	PWO	FWP

Table(4-4i)
Data collected from Northern Darfur state
Maintenance Frequency Table per Year- Per Pump
A:- INDIA MAKII HANDPUMP TYPE

Site	**Chain/ Coupling.**	**Handle bearing**	Water Tank	Plunger Rod	**Sealing Ring**	**Plunger Yoke Body**	**Rubber Seating small**	**Upper Valve**	**Pump Bucket**	**Rubber seating big**	**Check Valve**	**Conrod**	**Rising Pipe**	**Pump Condition**	**Spare Part Accessible**	**Main No./Year**	**Maintenance Cost (SD)**	
																	Lab.C	Spare. C
ABU SHOOK 1	2								1	1				Fair	No.	2/3	7000	4000
ABU SHOOK 2	2								1					Fait	No.	2/3	7000	3700
Al Rab Al wail	3		1		30				40		3	23	23	Bad	No.	61/4	213500	200700
Al Rab Al wail	4	2	1		32			6	15		4	23	23	Bad	No.	62/4	217000	200900
ABU ZRAKE11	4			1				3	30		2	10	8	Bad	No.	90/6	315000	259200
ABU ZRAKE 2	8								30		4	9	11	Bad	No.	12/6	42000	117000
ABU ZRAKE 3	6	5	4						18		20	3	4	Bad	No	25/6	87500	199500

Table (4-4ii)
B:- AFRIDEV HANDPUMP TYPE

Site	**Pump condition**	**Spare part accessible**	**H. F.P**	**Bush bearing**	**Rod hanger assy**	**Pin sleeve**	**Rod**		**Plunger valve**	**U-Seal**	**O- Ring**		**Pipe**		**Valve**		**MainFreq No./Year**	**Maintenance Cost (SD)**	
							Conrod	**Cent**			**Foot**	**Rec.**	**Cent**	**U.P.V.C**	**Foot**	**Bobbin**		**Lab. C**	**Spare. C**
ABU ZRAK4	Fair	No.												3	1		3/1	10500	16000
ABU ZRAK5	Fair	No.						1	1					1			2/1	7000	95000
ABU ZRAK6	Fair	No.												2			2/1	7000	10000

Note: -

Lab	Labour cost
PWO	Pay by WES project office
FWP	from WES Project
Cent	Centralizer
Rec.	Receiver
H.F.P	Head Fulcrum Pin

Table (4-6) Human being consumption Per Person per Day (lit) (El Ayara)

Season	Water for Drinking (lit)	Water for Cleaning (lit)	Water for Cooking (lit)	Water for Other (lit)	Total water consumption per day per person (lit)	Total Water consumption by the population (lit)
Autumn	4	6	4	4	18	27000
Winter	3	6	4	3	16	24000
Summer	7	8	4	4	23	34500

Table (4-6i) Livestock Consumption Per Day in lit (El Ayara)

Livestock	Number of Livestock in the Village	Water consumption in Dry Season per each (lit)	Water consumption in Winter Season per each (lit)	Total Water Consumption in Dry Season (lit) /	Total Water Consumption in Winter Season (lit)
Cows	10	30	18	300	180
Sheep's	100	6-8	4	800	400
Goats	20	8	4	160	80
Donkey	20	30	20	600	400
Camel	12	54	40	648	480
Total Water Consumption in				2508	1540

Table (4-7) Human being consumption per day in lit (Mahlia Muniki)

Season	**Water for Drinking (lit)**	**Water for Cleaning (lit)**	**Water for Cooking (lit)**	**Water for Other (lit)**	**Total water consumption per day per person (lit)**	**Total Water consumption by the population (lit)**
Autumn	4	8	4	4	20	113260
Winter	3	6	4	3	16	90608
Summer	6	8	4	4	22	124586

Table (4-7i) Livestock Consumption Per Day in lit (Mahlia Muniki)

Livestock	**Number of Livestock in the Village**	**Water consumption in Dry Season per each (lit)**	**Water Consumption in Winter Season per each (lit)**	**Total Water Consumption in Dry Season (lit)**	**Total Water Consumption in Winter Season (lit)**
Cows	200	32	16	6400	3200
Goats	100	4	3	400	300
Sheep's	250	4	2	1000	500
Total Water Consumption in				7800	4000

Table (4-8) Human being consumption per day in lit (Abu Zrake)

Season	Water for Drinking (lit)	Water for Cleaning (lit)	Water for Cooking (lit)	Water for Other (lit)	Total water consumption per day per person (lit)	Total Water consumption by the population (lit)
Autumn	4	8	4	4	20	120000
Winter	3	6	4	3	16	96000
Summer	6	8	4	4	22	132000

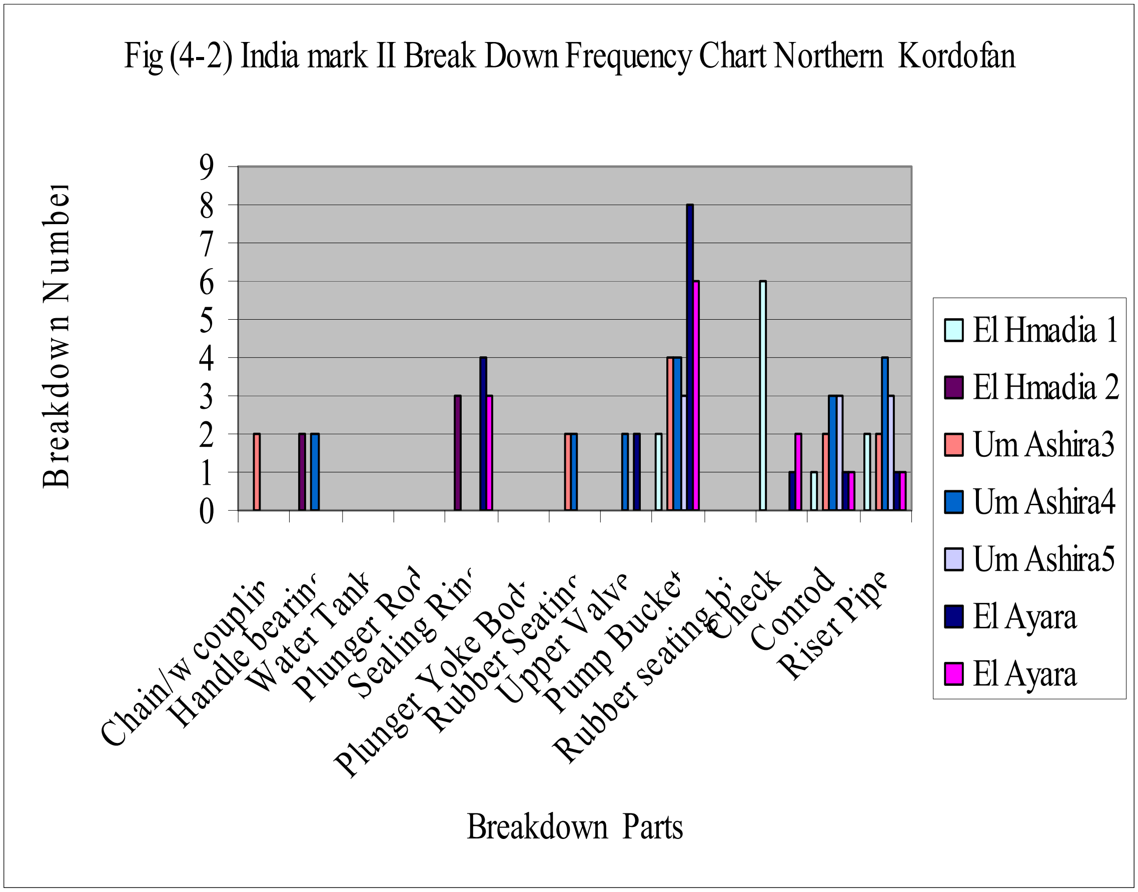
Table (4-8i) livestock consumption per day in lit (Abu Zrak)

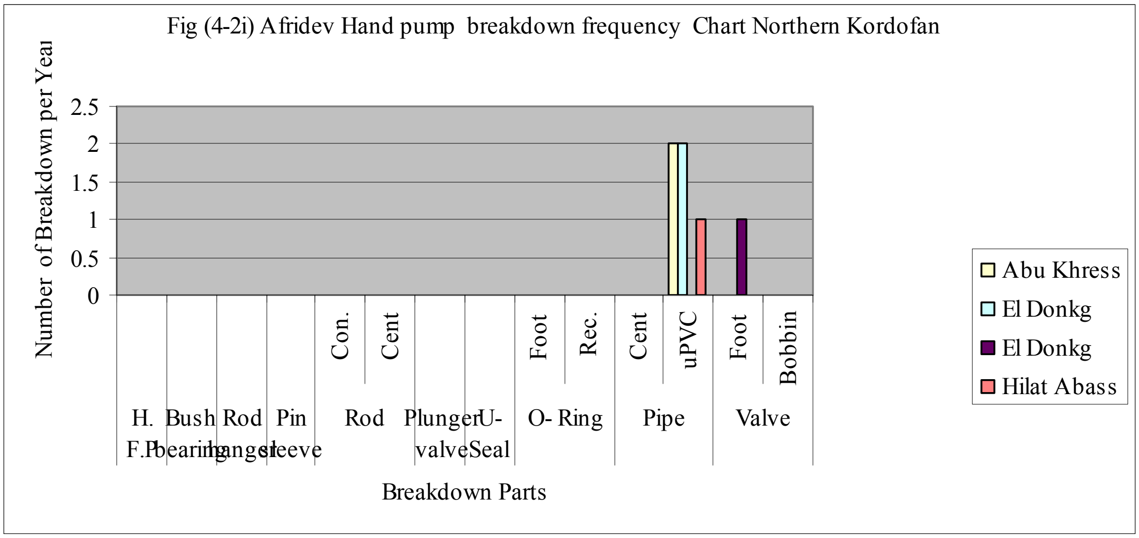
Livestock	Number of Livestock in the Village	Water consumption in Dry Season per each (lit)	Water Consumption in Winter Season per each (lit)	Total Water Consumption in Dry Season (lit)	Total Water Consumptior in Winter Season (lit)
Camels	100	54	40	5400	4000
Donkeys	2500	30	20	75000	50000
Sheeps/goats	2000	8	4	16000	8000
Cows	50	30	18	1500	900
Total Water Consumption in lit				97900	62900

`

4.8 <u>Data Analysis:</u>

Hand pumps technology will remain popular in Sudan rural areas with the three available hand pumps types; the India Mark II, Afridev and the locally produced Atbara type. Underneath is the field data analysis for three types hand pumps:-





From Figures. (4-2, 4-2i) for Northern Kordofan indicated that:-

- Hand pumps consumed a lot of connecting rods, rising mains in the El Hamadia and Um Ashira villages. The water pH is range between 6.2 up to 7.0 which means that corrosion of rising main pipes and pump rods are the main problems in the mentioned places, which means frequently replaced part fig (4-6).
- High consumption of the pump buckets and check valve at El Ayara and El Hamdia respectively. These mentioned sites the drilling depth and pumping setting depth range between 48-62 meters, which means that the pump setting depth is more than the designed depth of the pump.
- High consumption of sealing ring at El Hamdia / Um Ashira because of the frequent change of pump bucket.
- uPVC pipes in (El Donkog / Abu Khress) usually damaged at the socket joint (Design Failure) fig (4-8).
- Repair spare parts are not available at villages.
- Lack of hand pumps mechanics trained in some villages.

- In the summer, season the hand pumps operates days and nights to provide water for human being and live-stock.

Fig No. (4-3) Handpump Breakdown Frequency (Bahr El Jabal)

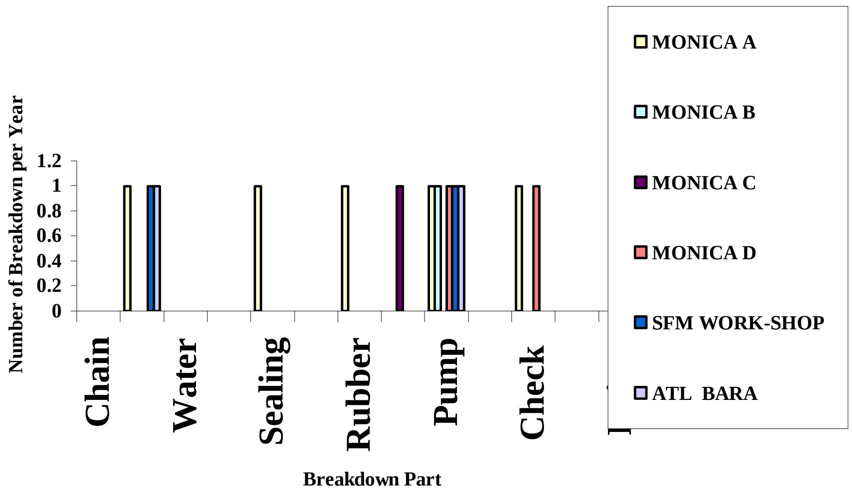


Figure No. (4-3) for Bahr El Jabel. Indicated that:-

- The pump buckets, upper valves, check valve and rubber sealing are the main problem.
- Water tariff collection system does not work properly.
- All the hand pumps maintenance is undertaken by WES projects.

Fig (4-4)India MarkII Handpump frequency Chart (Northern Darfur)

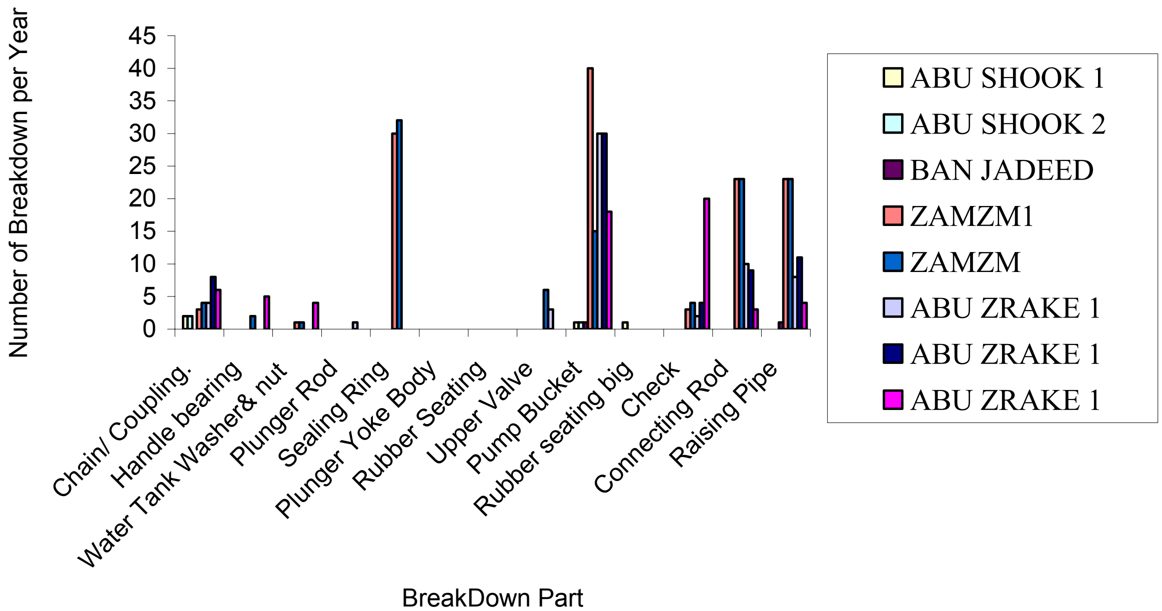
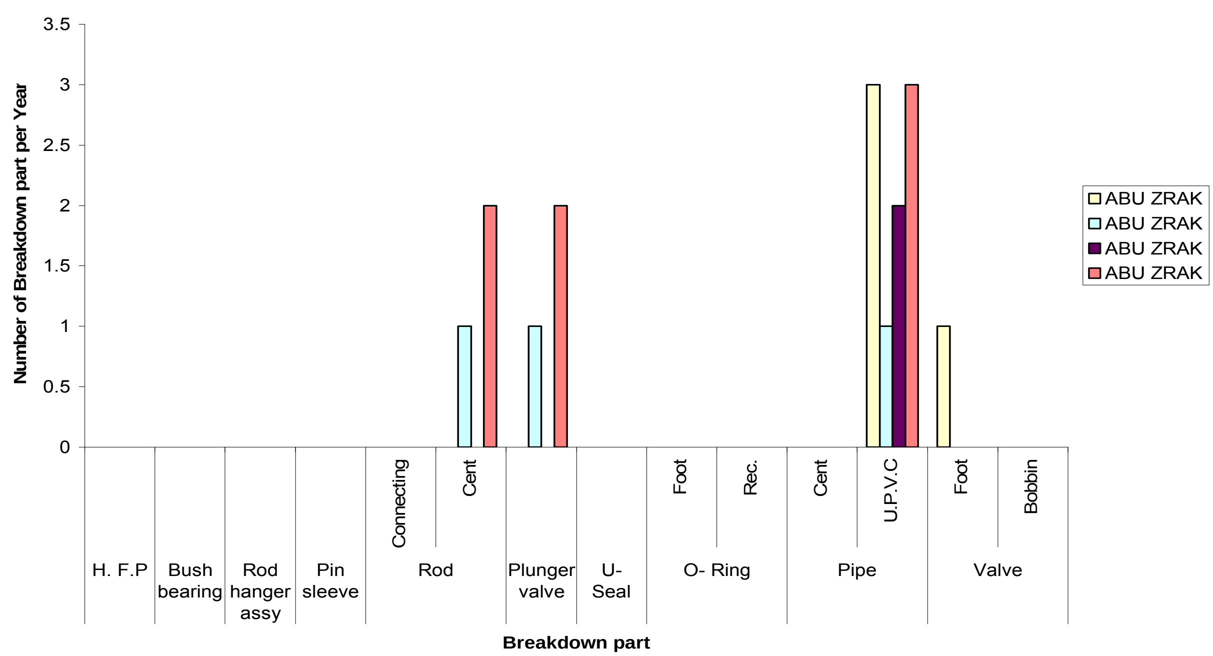


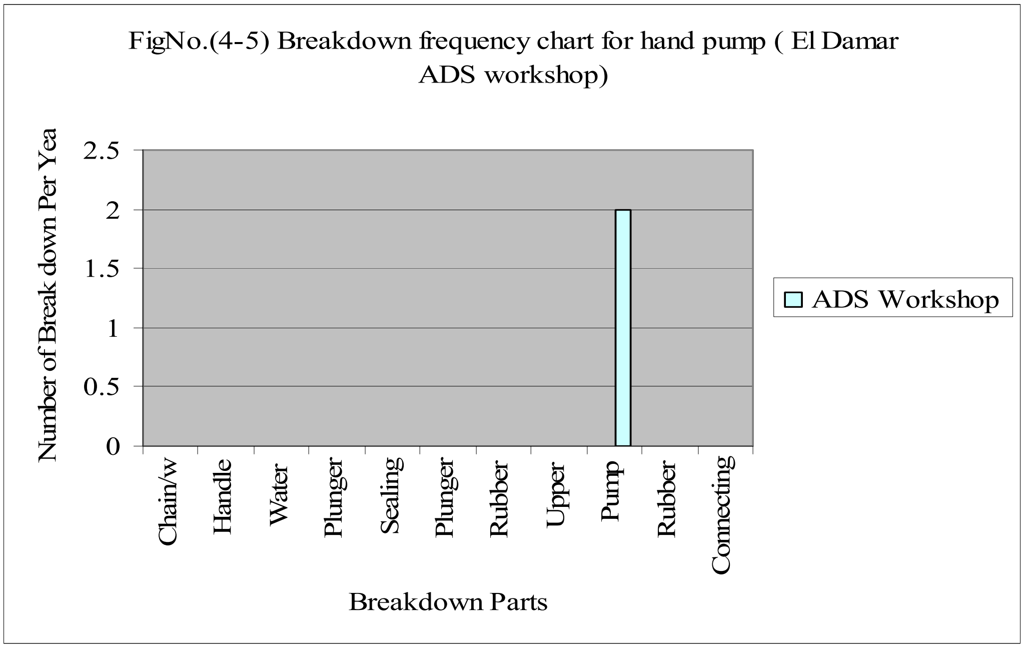
Fig No. (4-4i)Afridev handpump Breakdown frequency (Northern Darfur)



The Figures No. (4-4, 4-4i) from breakdown frequency table for Northern Darfur indicated that

- More pump buckets consumed in Al Rab Al wail and Abu Zrake
- Sealing ring is a big problem in Rab Al wail because the high changed of the pump buckets   match with sealing ring.

- Connecting rods and rising main pipes are also a problem at Rab Al wail because corrosion is a main problem as indicated in the fig (4-6). The field observations have shown that generally, where groundwater is moderately to highly aggressive (pH less than 7), galvanization of mild steel rising main pipes and pump rods do not protect them from corrosion. The effect of the corrosion on hand pumps is had two affects; one is mechanical performance which leading to broken rods and damaged pipes, secondly, corrosion which significantly affects water quality. The high iron concentration that results from corrosion makes water especially unacceptable to pump users because of its unpleasant taste and side effects such as discoloring.
- Abu Zrake is a combination of five big villages. All of the population and livestock watering from these six hand pumps during dry season. That means the pump works day and night but does not satisfy the demand.
- No sale centre at these villages, the parts available at El Fashir in WES project and one merchant man at local market (expensive).
- The health committee is very strong in the collection of water tariff at these sites but the money is not utilized at the right channel in the improvement of water services.
- Check valves are really a problem in Northern Darfur
- uPVC rising main pipe is problem at Northern Darfur fig (4-87) .



The figure No. (4-5) showed hand pumps breakdown parts at El Dammar (ADS workshop) indicated that:-

The hand pumps consumed more pump buckets in the first years. In spite of the fact that the pump setting depth is 12 meters (The Cylinder designed in El Damar).

The following method is usually applied by the hand pumps mechanics at the field to avoid check valve failure result in increment increase in the length of the connecting rod. -

i*The first step After installing the water tank, they pushed rod down as possible and mark rod in the level at the top of water tank then by Lifting the connect rod as far as possible with the help of connecting rod lifter to rod and insert connecting rod vice.

ii* The second Step Putting cloth a round top of connecting rod vice and start cutting rod above the mark 16 cm.

iii* The third Step Cut thread on the rod for 45 mm length assist with lubrication fluid (oil) during cutting, then screw the nut by hand.

iv*Then the process of installation is complete.

But this method is inapplicable because for long use of the connect rod, the diameter of the rod squeezes and will subject to tensile failure in the future.

Fig(4-6) Corrosion of the Galvanized pipe and Connecting rod for India MarkII hand pumps

Fig. (4-7) Damage of uPVC pipe

Fig. (4-8) uPVC rising main failure

Water Tariff: -

There is no fixed system of water tariff collection in study area. The used one is come out of the community due to mobilization and support from the WES projects and SWC at the states. There are many different systems adopting for water tariff collection like:

a- Tariff per family per month: - which is applied for the majority of Hand-pumps in the state.

b- Tariff per quantity:- This system is very well managed by appointing a guard for each hand pump to supervise day to day work and collect money from the users to be funded to the water committee established for that purpose . Another system was introduced by nominating a number of pumps as investment source for watering animals. In animal watering systems, the committee makes agreement with nomads upon certain tariff per cattle per month.

c- Irregular tariff:- this is paid only for repairs and maintenance at the time when breakdown occurs. This system is mainly in towns like. The communities of such towns really do not take care of hand pumps only when breakdown happens and water crisis rises.

Hand pumps water tariff collection in the whole states is applied only from November to June, after that it becomes free of charge because people drink from Haffirs and Pools which are not healthy, that is because of lack of awareness regarding safe clean and healthy drinking water.

Chapter V

CHAPTER FIVE

WATER WELL DRILLING

5.1 Introduction

Drilled wells or boreholes are constructed by drilling machine or hand-operated equipment's to abstraction of the ground water from deep aquifer. Borehole general diameters vary between .10m and .25m. The drilling of the boreholes is usually the most expensive part in the water yards.

5.2 Well Site

The well site by geophysical survey is normally conducted by professional team to inspect and identify well location. The team equipped with geo-hydrological Instruments or hydrological map to identify location (longitude, latitude and attitude). Other instruments like geophysical logging (magnetic and electromagnetic method) for reflection of water availability.

The identification of the sites include geophysical survey some time gives negative result.

5.3 Well depth

The drilling of the boreholes depends mainly on the site identification report, in which status of the total depth, static water level and the type of formation are predicted .The drilling depth depends mainly on the water basins for the selected site: -

Nubian Basin	Depth to water ranges from 10-120 Meter
Um Ruwaba Basin	Depth to water ranges from 10-75 Meter
Nubian/ Um Ruwaba Basin	Depth to water range from 10-75 Meter
Nubian Basalt Basin	Depth to water ranges from 25-75 Meter
Alluvial Basin	Depth to water ranges from 3-10 Meter

Ref [29].

5.4 Drilling rig:-

Different types of the drilling rigs were used in the drilling of the hand pumps in Sudan. The selection of the right drilling equipment depends mainly on the local geology formation of the sites and depth. In basement complex form preferable hammer pneumatic drilling rigs, the sand area the mud pump with rotary rigs is preferable and in both sand and clay formation a combined drilling rig is suited. Following are common types of drilling rigs:-

5.4 .1Cable Tool Drilling Rig

Developed by the Chinese, the tool percussion method was the earliest drilling method and has been in continuous use for a long time. The early Chinese could drill wells to a depth of 3,000 ft (915m). Cable tool drilling machines, also called percussion or (sputter) rigs operated by repeatedly lifting and dropping a heavy drill bit to breaks or crushes consolidated rock into small fragments, whereas the bit primarily loosens the material when drilling in unconsolidated formations. In both instances, the reciprocating action of the tools mixes the crushed loosened particles with water to form a slurry or sludge at the bottom of the borehole. If little or no water is present in the penetrated formation, water is added to form slurry. Slurry accumulation increases as drilling proceeds and eventually reduces the impact of the tools. When the penetration rate becomes unacceptable, slurry is removed at intervals from the borehole by a sand pump or bailer.

Cable tool drilling equipment consists of five components drill bit, drill stem, drilling jars, swivel socket, and cable. Each component has an important function in the drilling process. The cable tool bit is usually massive and heavy so as to crush and mix all types of earth materials. The drill stem gives additional weight to the bit, and it is length helps to maintain a straight hole when drilling in hard rock Fig. (5-1).

Drilling jars consist of a pair of linked, heat-treated steel bars. When the bit is stuck, it can be freed most of the time by upward blows of the free- sliding jars. This primary function of the drilling jars. The stroke of the drilling jars is 9 to 18 in (229 to 457 mm) and distinguishes them form fishing jars which have stroke of 18 to 36 in(457 to 914 mm) or longer. The swivel socket connects the string of tools to the cable Fig. (5-2).

5.4 .2 Direct Rotary Drilling Rig

The direct rotary drilling was developed to increase drilling speeds and to reach greater depths in most formations. The borehole is drilled by rotating a bit and cutting are removed by continuous circulation of a drilling fluid as the bit penetrates the formation. The bit is attached to the lower of a string of drill pipe, which transmits the rotating action from the rig to the bit. In the direct rotary system, drilling fluid is pumped down through the drill pipe and out through the ports or jets in the bit .the fluid then flows upward in the annular space between the hole and drill pipe, carrying the cuttings in suspension to the surface. At the surface, the fluid is channeled into a setting pit or pits where most of the cutting drop out. Clean fluid is then picked up by the pump at the far end of the pit or from the second pit and is re-circulated down the hole Fig. (5-3).

5.4 .3 Air drilling Rig

In the air rotary method, air lifts the cutting from the borehole from the large compressor that is piped to the swivel hose connected to the top of the drill pipe.

The air forces down the drill pipe, thereby lifting the cuttings and cooling the bit. The cuttings are blown out the top of the hole and collect at the surface.

Air drilling can be done only on in semi consolidated or consolidated materials, to operate in completely unconsolidated as well as consolidated formations, air rotary drilling machines are often equipped with mud pump Fig. (5-4).

Table (5-1) Types of the drilling rigs

N#	Typ Drilling Rig	Components of the Drilling rig	Max. Drilling Depth (m)
01	Hammer Rig	Drilling machine + Air Compressor	Up to 200m
02	Combined Rig	Drilling machine with Mud Pump + Air Compressor	Up to 1000m
03	Cable Tool Rig	Cable Drilling equipment's	Up to 100m
04	Hand Drilling machine	Drilling equipment's	Up to 20m

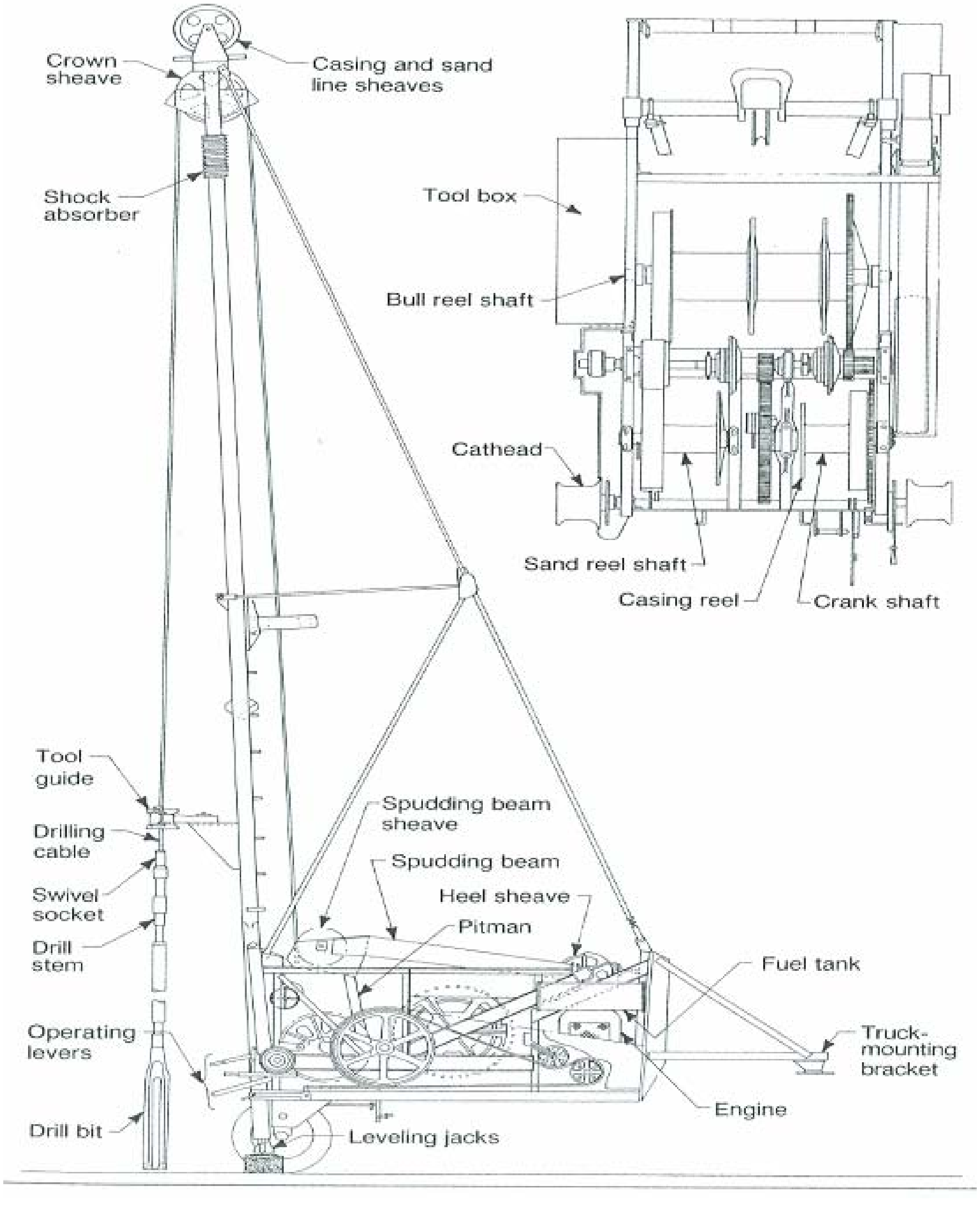


Fig. (5-1) Cable tool Drilling Rig

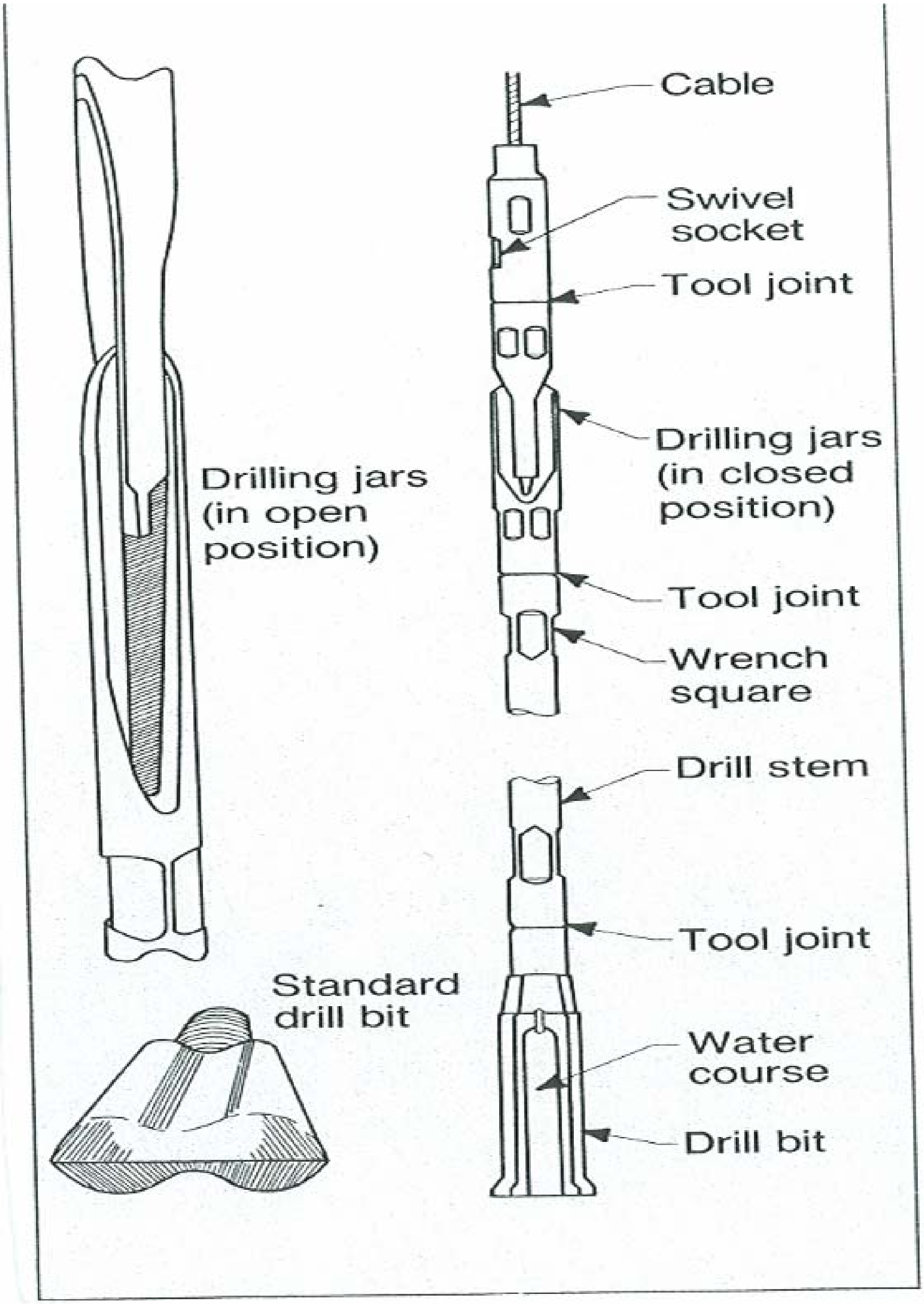


Fig. (5-2) Drilling tool for Cable tool rig

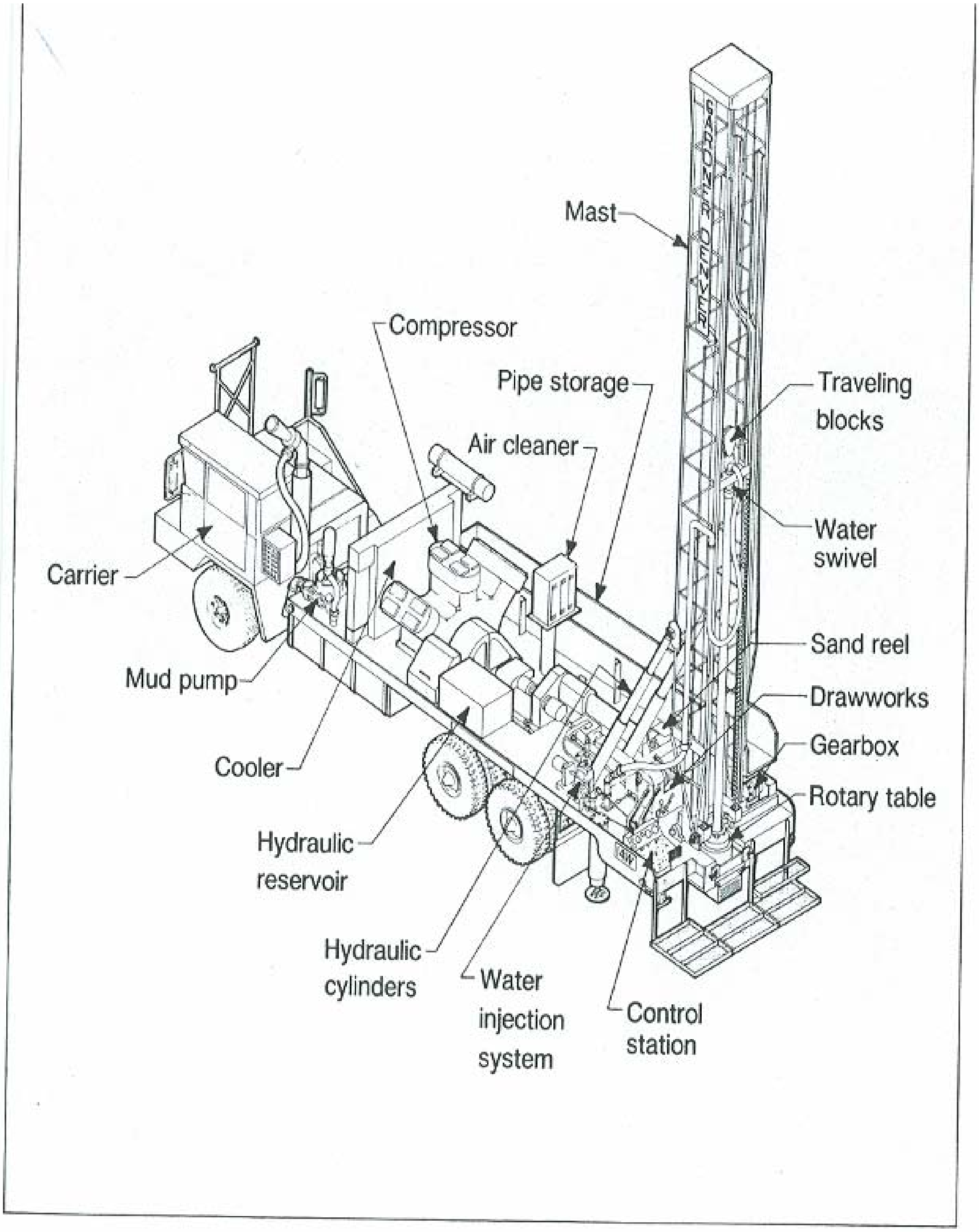
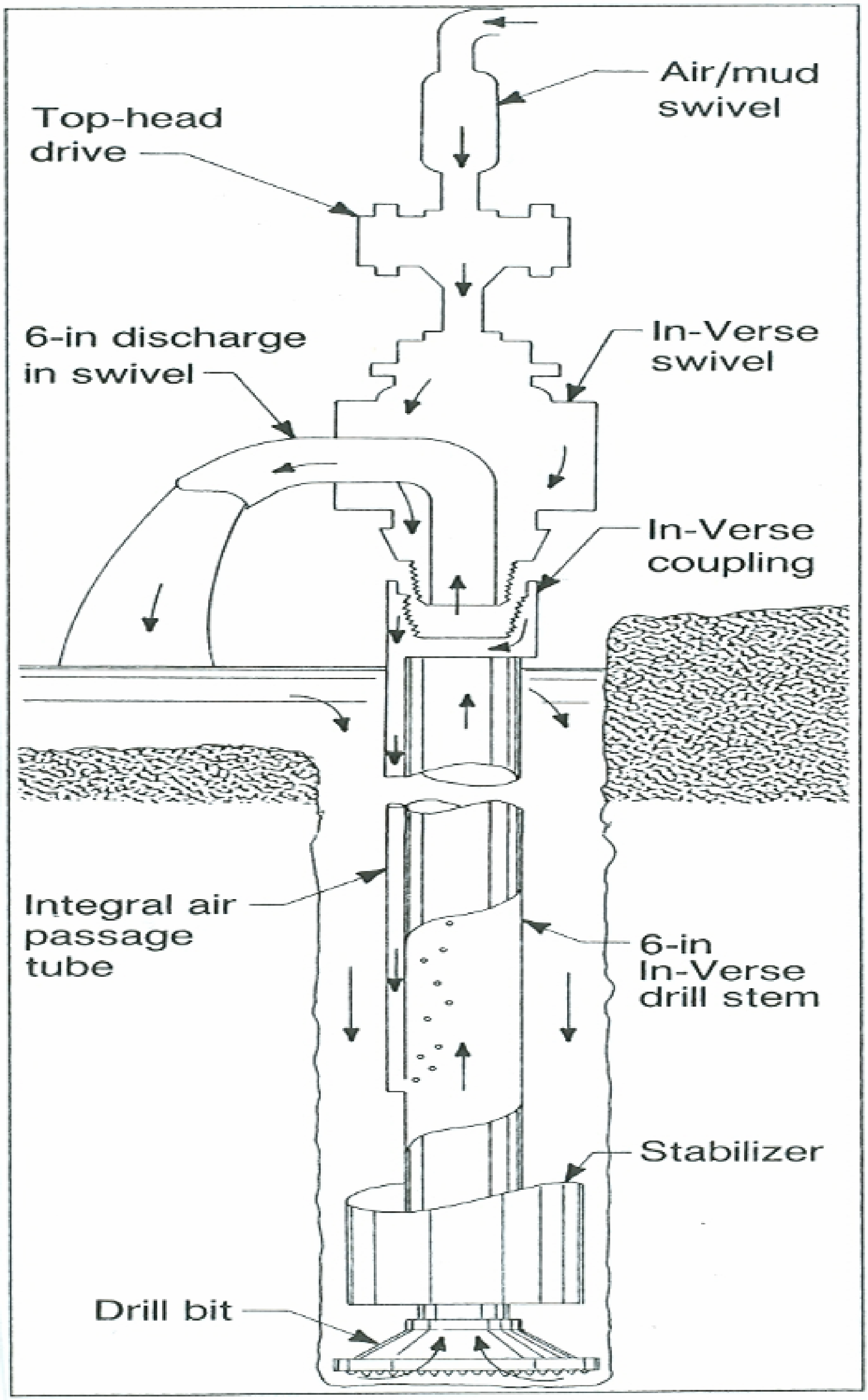


Fig. (5-3) Section of Rotary Drilling Rig



Air/mud
swivel
Top-head
drive
6-in discharge
in swivel
In-Verse
swivel
In-Verse
coupling
Integral air
passage
tube
6-in
In-Verse
drill stem
Stabilizer
Drill bit

Fig. (5-4) Hammer Drilling Rig

5.5 Drilling Techniques

The boreholes site cleary identified by the supervising engineer (Site name, coordinates, province and state).The drilling operation initiated by adjustment of the drilling rig mast with use of water level indicator and this step before the drilling proccess, The strata collectes continuously every two meters, moreover, a sample will be collected at each change in drilling pipe replacement.

In the mud drilling full consideration to the mud properties like density, funnel viscosity, filtrate losses, sand content, resistively and pH will be continuously checked.

The completion of wells shall be approved by the supervising engineer in accordance to the geological formations on each particular site. The actually drilled depth may exceed the proposed depth hence the supervising engineer approves the finished depth of each well.

To prevent contamination from the surface the casing top is coated in a concrete slab constructed at the top ground surface level around the casing.

The drilling logs and comments on drilling characteristic (such as fluid loss, penetration rate, etc) record in the borehole report.

Immediately after completion of the work all necessary precautions to ensure the safety of the site are taken with all prevailing safety regulations, for the removing of the native silts, clays and drilling fluid residues deposit during the drilling process, the development process should be immediately after completion of the drilling process and continue up to the satisfaction of the supervising engineer.

The development shall be done in a manner that does not cause under settlement and disturb the strata above the water bearing formation, the test pump complete with movers used in pumping should be a very high efficiency equipment.

The water sample collected in standard method and sent to an approved laboratory, for the following tests :-

5.6 Physical and chemical analysis

5.6.1 Physical properties:

Color, turbidity, odor, taste temperature and disol. Oxygen.

5.6.2 <u>Chemical properties</u>:

The chemical analysis data were collected from water wells .The chemical data include the most important and physical porperties of the ground water, which are The specific electrical conductivity (EC) , Hydrogn ion concentration (pH) , Total Hardness (TH), Total Alkalinity (T.ALK) and total dissolved solids (TDS)in natural waters(e.g. Na^{+}, K^{+},Ca^{+},Mg^{++}, Hco_3^{-},CL-, So_4^{--}, F^{-}, etc.).

Chemical species are expressed in parts per million (ppm), equivalent per million (epm) and equivalent per million percentage (epm%).

5.6.3 <u>Radioactivity analysis</u>:

In bull gross alpha activity, gross beta activity.

5.6.4 <u>Bacteriological and biological analysis</u>:

1st. E, coli or thermotolerant coliform bacteria.

2nd. Pathogenic intestinal protozoa Total coliform bacteria

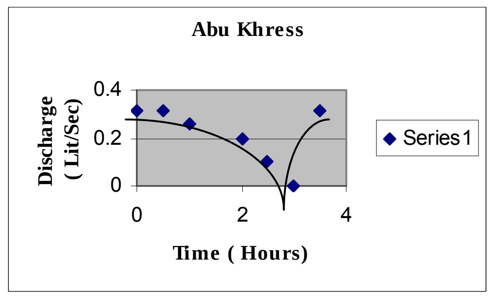
5.7 <u>Factors Affecting Boreholes Performance</u>

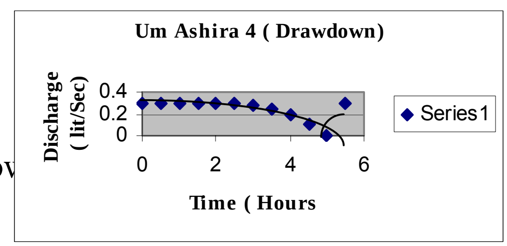
Following is main factors affecting boreholes performance from survey:-

Drawdown of the water Table

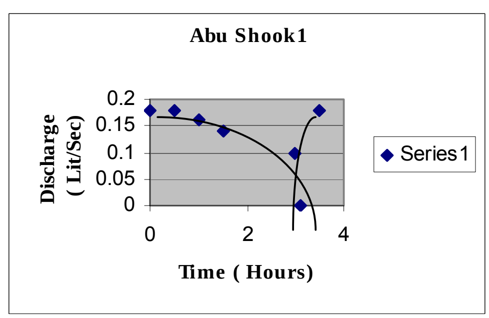
Basement rocks which across large areas of upland Africa and Asia are essentially impermeable crystaline rocks and transmit water only when fractured or weathered. Deep weathering is common in tropical wet areas. These rocks permeability is low and can provide an adequate aquifer for widespread development of hand pump based rural water supplies. In these basement when maximum yield of the well is the same as the pump discharge excessive drawdown can result, and brings pumping water level down to the level of the cylinder intake. When that happens air pumping may occur. possiblly accompanied by sand movement and damage seal. The drawdown can be expressed as difference measured in feet or meter between the water table or potentiometric surface and the pumping water level .

In **Northern Kordofan** the draw down in some boreholes (Jamma) Table 3-1ii Is very serious, recovery of the boreholes Some times reaches 30 minutes as in Both Abu Khress and Um Ashira 4 (Charts).





In **Northern Darfur** (Abu Shook 1) the drawdown is much in the summer season in the massive Population area. The pump operates more than 18 hours. The recovery of the borehole Needs more than 30 minutes, chart Table 3-2ii



Drawdown and Recovery of Boreholes

Table(5-2)

Data collected from Northern Kordofan state

Skeikan Province (Abu Khress)				Skeikan Province (Um Ashira 4)			
No.	**Time (Minutes)**	**Depth of water in (m)**	**Discharge (Lit/Sec)**	**No.**	**Time (Minutes)**	**Depth of water in (m)**	**Discharge (Lit/Sec)**
1	0	*	0.31	1	0	*	0.29
2	30	*	0.31	2	30	*	0.29
3	60	*	0.26	3	60	*	0.29
4	120	*	0.20	4	90	*	0.29
5	150	*	0.10	5	120	*	0.29
6	180	*	0	6	150	*	0.29
7	210	*	0.31	7	180	*	0.28
				8	210	*	0.24
				9	240	*	0.20
				10	270	*	0.10
				11	300	*	0
				12	320	*	0.29

Draw down and Recovery of Boreholes

Table (5-3)

Data collected from Northern Darfur state

El Fashir Province (Abu Shook 1)			
No.	**Time (Minutes)**	**Depth of water in (m)**	**Discharge (lit/Sec)**
1	0	*	0.18
2	30	*	0.18
3	60	*	0.16
4	90	*	0.14
5	180	*	0.10
6	190	*	0
7	210	*	0.18

5.8 <u>Summary of finding</u>

The field sites visited presented with data analysis have produced considerable new evidence about the handpumps functions and the factors influencing their perforamnce and reliability.

Following are the main problems that caused failure to the India MarkII, Afridev and Atbara type hand-pumps as evaluated from field visited.

5.8.1 **India Mark II Hand-pumps**

a. Corrison Resistance :-

High failure rates of galvanized rising main pipes in the corrosive ground water found particularly in Kordofan - Darfur region , out of 5 broken hand-pump experienced, one was due to corrosion The incidence and extent of corrosion damage depends mainly on two factors , pump component materials and ground water quality.

b. Abrassion :-

The frequently damage of the pump bucket, leather cup and sealing ring is result from sand- Laden water, that abraded the inner of the cylinder and wearing of the cylinder components

A modified pump bucket done by replacing leather it with Nitrile rubber seal gave some improvement , but still the rubber doesn't live long time , that means problem exist (Breakdown Frequency Tables).

c. Repair Part Replaced:-

Most of the hand-pumps in Kordofan – Darfur recorded more breakdown and high consumption of the repair parts like(Check Valves and connecting rods).usually check valves replacement occurred in short interval of time . The breakdown of the check valve resulted from impact forces between the upper plunger valve and the check valve,as a result of increase in length of the connecting rod.

5.8.2 **Afridev Hand pump**

Afridev handpump designed for installation at borehole depth not more than 45 m.The pump main advantage is that its light in weight and pumping force decribed as VLOM Type pump for low yield.This hand pump has following disadvantages :-

a. **User Perferance**

Most of user perfere India Mak II rather than the other pump, despite of some disadvantages of the India Mark II.

c. Repair part Replaced:

Afridev pump have been found unsuitable in most areas due to frequent damage and breaks of the rising main pipes.

5.8.3 **Atbara Type Hand-pumps:-**

The only factors that decrease perfomance of the above mentioned pumps is leather rubber damages and the riser pipe corrosion.

5.8.4 **Community Management :**

There are different methods of collection of water tariffs but all these methods equally did not achieve sustainable water supply in the villages, because all the money collected by the health committee is being used by government (Mahlia) council or RWC instead of being used as a revolving fund and put in an account to facilitate the repair parts or estabilish a sales center.

Chapter VI

CHAPTER SIX

Experimental Work

6.1 Introduction

The experimental work was conducted to evaluate the failure of some hand-pumps parts. Three series of experiments were undertaken as follows:

Experiment Number One:

This experiment was done to determine the modulus Elasticity of uPVC pipe and Strain.

Experiment Number Two:

This experiment was performed to determine the tensile strength of uPVC by determining the load and cross section area.

The result from these two experiments gave the actual ultimate tensile strength of uPVC .

Experiment Number Three:

This experiment is done mainly to determine the elongation of the India MakII connecting rod to identify the increase in length of connecting rod beside the impact load of upper valve against check valve.

6.2 Experiment One: -

The apparatus (figure 6-1) consist of the following:

- Two vertical support (made from steel U- Section) with 1000mm height from ground.

-Galvanized pipe of diameter 31.75 mm, length 15 mm, welded at the top center of U-Section. Two-pieces of sheet (100X20 mm^2) welded at the end of pipe for supporting the tested material.

-Scaled Dial gauge (one Unit =0.01 mm) supported by reinforcement bar fixed at the two ends. The U- Section lengths vary according to the required span.

-Masses made from cast iron range from 2.2 kg up to 8.9 kg used.

-Masses carrier made from rod 200 mm and welded circular steel sheet carrier at the end.

2**. Tested Material**

Unplasticied polyvinyl chloride pipe with inner diameter 53.6 mm and outer diameter 63 mm. The tests lengths are 1600mm,1400mm and 1200 mm respectivelly .

3. **Procedure of Experiment**

The modulus of elasticity determined from simple bending tests carried out on uPVC pipe with inner dia 53.6 mm , out Dia 63.0 mm with a total length of 200m. The experiment is carrreied four times by reducing the length of the test span from 1600 mm to 1400 mm and to 1200 mm as follows:

1- The vertical support in 1600 mm span and the load carrier fixed with dial gauge at the middle of the span .

2- Applying load of 8.9 kg.

3-The deflection was measured.

4- The load inceased incrementaly up to 62.2 kg.

5- The deflection records were taken for each load increment.

6- This experiment was done twice by reducing the span to 1400 mm and 1200mm with initial loads 8.9 Kgs, 11.1 Kgs and 13.3 kgs respectivelly.

7- The results of the experiments are tabulated in the tables (6-1, 6-2, 6-3 and 6-4).

8-The analysis of the results for the uPVC behavior against the load is shown in Figs. (6-2, 6-3, 6-4 and 6-5).

4. **Calculation**

The calculation of the experiments results were done by using the following formula:

Deflection = $\frac{PL^3}{48EI}$ (Mohrs Theorm).

E = Modulus of Elasticity

P = Load

L = Length of Span

E = $\mathbf{\frac{(P/Deflection) \times L^3}{48I}}$

I = $\mathbf{\frac{\pi (D^4-d^4)}{64}}$

P/Deflection = from figures (6-2, 6-3, 6-4 and 6-5)

Table (6-5) Result and Average of Experiment No.1

No	Test	Length of Span (mm)	P/Deflection (kg/mm)	E(kg/ mm^2)
01	First test	1600	1.1	254.8
02	Second test	1400	1.8	279.4
03	Third test	1200	2.6	254.16
04	Fourth Test	1200	1.98	193.56

From Table (6-5) the average Modulus of Elasticity Equal

$$E = \frac{254.8+279.4+254.16+193.56}{4}$$

E = 245.48 kg/ mm^2

Experiment One

Table No. (6-1) Load – Deflection Reading (Span 160cm).

For Un-plasticized Polyvinyl Chloride Pipe (uP.V.C)

No.	Load in (Kg)	Deflection in (mm)
01	0	0
02	8.9	6.21

03	17.8	12.38
04	26.7	18.72
05	31.1	21.97
06	35.6	25.26
07	40	28.67
08	44.4	31.97
09	48.9	35.59
10	53.3	39.2
11	57.8	42.87
12	60	44.55
13	62.2	46.37

Experiment One

Table No. (6-2) Load – Deflection Reading (Span 140cm)

For Un-plasticized Polyvinyl Chloride Pipe (uPVC)

No.	Load in (Kg)	Deflection in (mm)
01	0	0
02	8.9	0.79
03	17.8	3.36
04	26.7	6.12
05	31.1	7.5
06	35.6	9.85
07	40	10.24
08	44.4	11.48
09	48.9	13.11
10	53.3	14.55
11	57.8	16.02
12	62.2	17.6
13	66.7	18.97
14	71.1	20.52

Experiment One

Table No. (6-3) Load – Deflection Reading Span (120 cm)

No.	Load in (Kg)	Deflection in (mm)
01	0	0
02	11.1	1.3
03	13.3	4

04	22.2	6.4
05	31.1	9.38
06	40	12.15
07	44.4	13.56
08	48.9	14.96
09	53.3	16.4
10	57.8	17.87
11	62.2	19.31
12	66.7	20.77
13	71.1	22.23
14	80	23.8
15	84.4	25.62
16	89.4	27.05
17	94.4	28.8
18	99.3	30.53
19	104.4	32.41
20	109.4	34.29

Experiment One

Table No. (6-4) Load – Deflection Reading Span(120 cm)

No.	Load in (Kg)	Deflection in (mm)
01	0	0
02	13.3	5.01
03	22.2	10.16
04	31.1	14.64
05	40	19.24
06	48.9	23.98
07	57.7	28.59
08	66.7	33.29
09	75.6	38.46
10	80	42.02
11	85	45.14
12	90	47.44
13	95	50.64

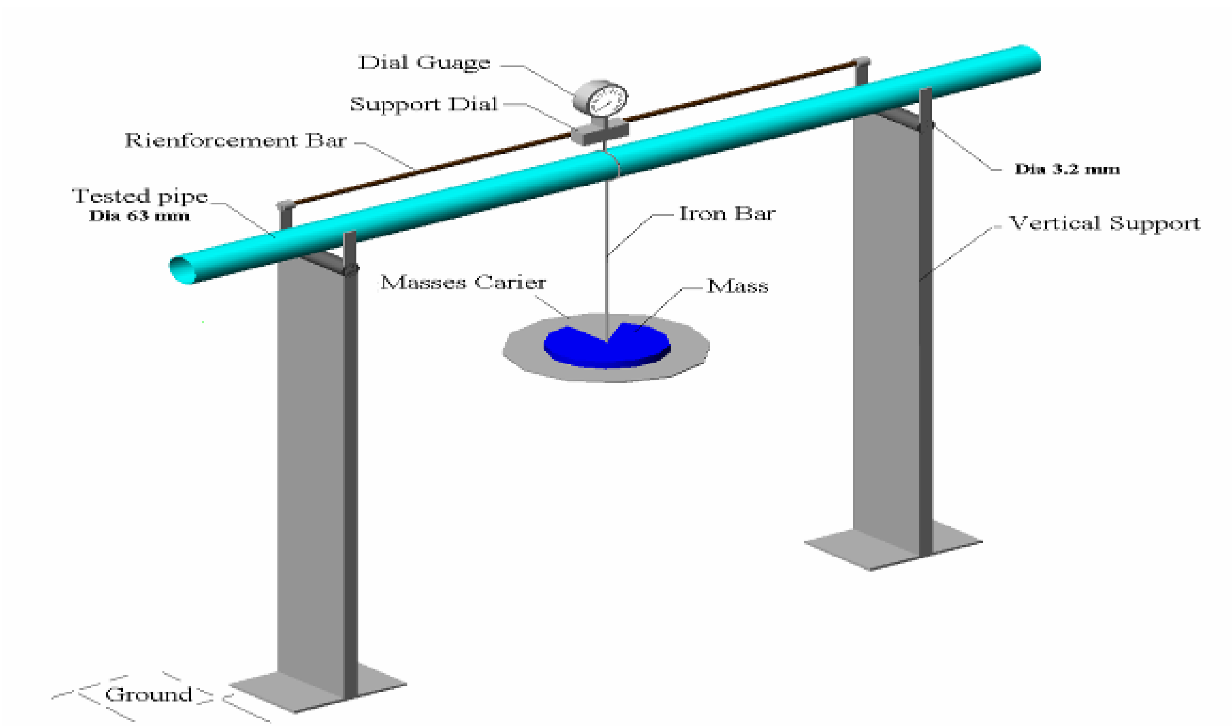


Fig (6-1) Testing Apparatus

Fig. No. (6-2)
For Table No.(6-1)Load -Deflection Reading For Unplasticied Polyvinyl Choride Pipe
(uP.V.C) Raising Main for Afridev Handpump)

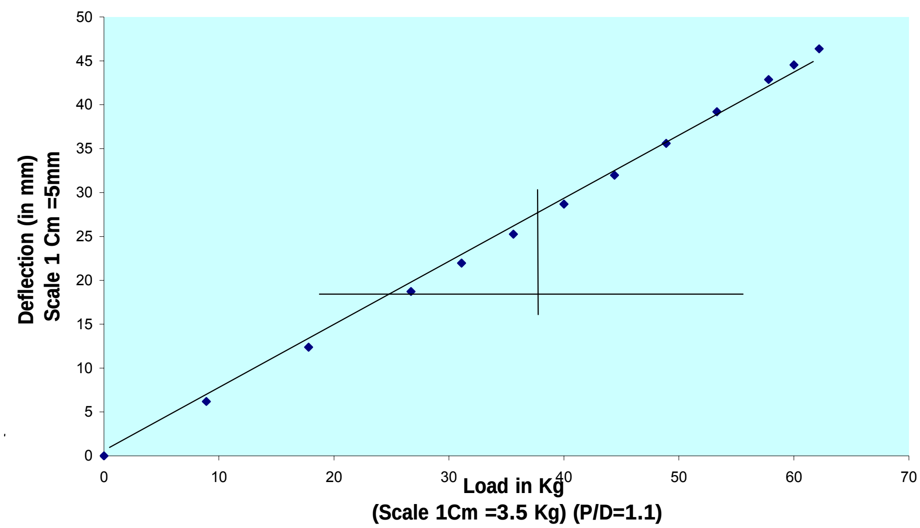


Fig. No. (6-3)
For Table No. (6-2)Load - Deflection Reading For Unplasticied Polyvinyl Choride Pipe
(u P.V.C) Raising Main For Afridev Handpump

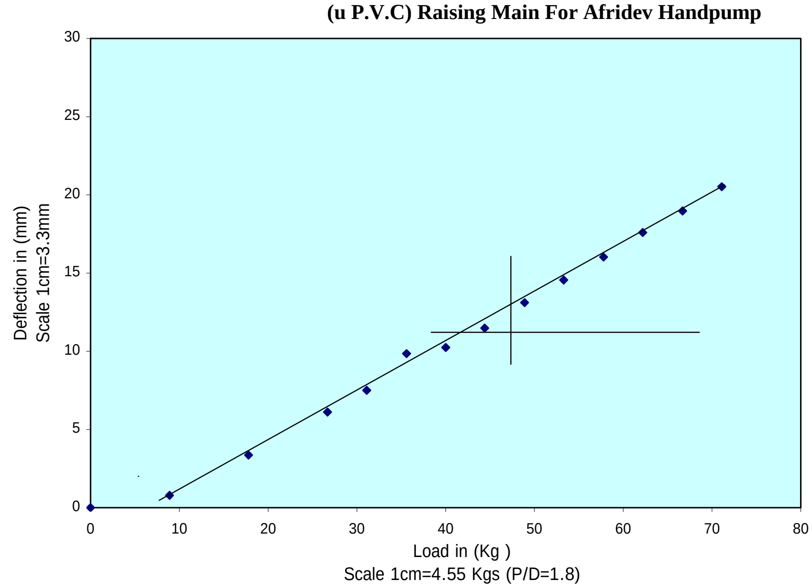


Fig. (6-4)
For Table No. (6-3) Load -Deflection Reading For Unplasticied Polyvinyl Choride Pipe (uP.V.C) Raising Main for Afridev Handpump

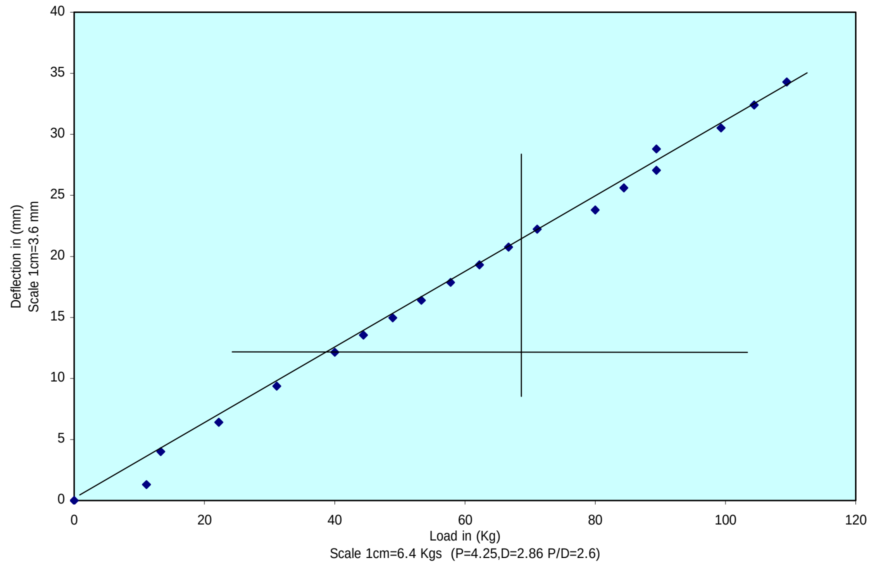
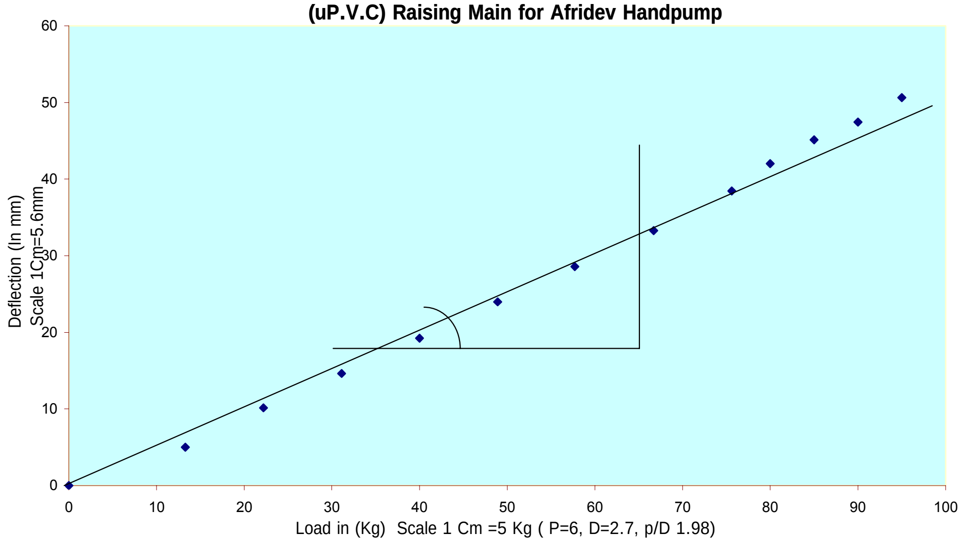


Fig No. (6-5)
For Table No.(6-4)Load - Deflection Reading For Unplasticied Polyinyl Choride Pipe (uP.V.C) Raising Main for Afridev Handpump



6.3 <u>Experiment Two: -</u>

Determination of uPVC pipe ultimate tensile Strength . The tensile strength of Un-plasticized Polyvinyl Choride pipe determined from tension test carried on the test machine in the strength of materials laboratory at the department of civil engineering, University of Khartoum.

1. Apparatus of the Experiment

A/ Test Machine

Avery Birmingham weighing and counting test machine with maximum capacity 30 ton type A806/ 1474 serial no. E45303 /308. Scale range from 0.1 ton up to 30 ton.

B/ Strain Measurement devices

Strain Gauge Scale range from 0 up to 3000 unit each

1 unit =0.002 mm

-Elongation ruller in inchs

2. Test Specimen

Specimen cutting from uPVC pipe inner diameter 53.6 mm , out diameter 63 mm and 63.6 mm inner and 73 mm outer at the joint socket . Dimension of the tested specimen as in Fig(6-6) :-

Total length of the specimen	600 mm
Width of Specimen	44 mm
Thickness of Specimen	4.7 mm

Support rubber layers fixed at the top 70 mm and bottom of specimen 70 mm

3. Procedure: -

The test specimen fixed at the upper and lower clamp on the test machine at a distance 100 mm above and below Fig(6-6).

1-Zero reading was evaluated from strain gauge

2-The loads were applied in increments of (50 kgs) to the test specimen.

3-Readings of elongation, width and thickness taken by using strain gauge and the ruler.

4- Different loads from 100,150-600 kgs applied and the elongation/ width and thickness recorded in table (6-6)

Table (6-6) Experimental Data

No.	**Load (F) (kgs)**	**Elongation (L-Lo) (mm)**	**Width (W) (mm)**	**Thickness (t) (mm)**
01	0.00	0.000	0.00	0.0
02	50	0.096	44.0	4.7
03	100	0.198	44.0	4.7
04	150	0.278	44.0	4.7
05	200	0.414	43.9	4.6
06	250	0.508	43.8	4.6
07	300	0.634	43.3	4.6
08	350	0.724	43.2	4.6
09	400	0.828	42.9	4.6
10	450	0.954	42.8	4.5
11	500	1.086	42.7	4.5
12	600	1.306	42.6	4.48
13	700	1.53	42.3	4.4

4. Calculation:

The stress evaluated by using the two methods is calculated hereunder.

A/ to calculate the stress by using formula

$$\text{Stress} = \frac{\text{Applied load}}{\text{Cross- section Area}} \qquad \sigma = F/A \qquad = \text{kg f/ mm}^2$$

From Table (6-6)

F = Applied load =50 kgfs

B = Cross section area of the test specimen = 44X4.7= 206.8 mm^2

$$\text{Stress} = \frac{\text{Applied load}}{\text{Cross- section Area}} = \frac{50}{206.8} = 0.241 \text{ kg f/mm}^2 \quad \text{Ref.table (6-6)}$$

B/ to calculate the stress by using formula: -

Strain = Elongation / Length

Stress = Modulus of Elasticity X Strain

σ = EXS

E Modulus of Elasticity = 245.48 kg/ mm^2 Ref. Exp. No. (1)

S Strain of material = 0.096 ⁄ 100 Ref. table (6-6)

Stress from = 245.48 x0.00096 = 0.236 kg/ mm^2 Ref. table (6-6)

Table (6-7) Result for Experiments No. One and Two

No	Load (F) (kgs)	Elongation (L-L0) (mm)	Width (w) (mm)	Thickness (t) (mm)	Area (wxt) (mm^2)	Stress F/A (kgs/ mm^2)	Stress EXS (kg/mm^2)
01	0.00	0.000	0.00	0.0	0.00	0.00	0.00
02	50	0.096	44.0	4.7	206.8	0.241	0.236
03	100	0.198	44.0	4.7	206.8	0.4835	0.4860
04	150	0.278	44.0	4.7	206.8	0.725	0.6824
05	200	0.414	43.9	4.6	201.94	0.99	1.016
06	250	0.508	43.8	4.6	201.48	1.240	1.247
07	300	0.634	43.3	4.6	199.18	1.506	1.556
08	350	0.724	43.2	4.6	198.72	1.7612	1.777
09	400	0.828	42.9	4.6	197.34	2.0266	2.0325
10	450	0.954	42.8	4.5	192.60	2.3364	2.3418
11	500	1.086	42.7	4.5	192.18	2.6017	2.6659
12	600	1.306	42.6	4.48	187.44	3.2010	3.205
13	700	1.53	42.3	4.4	186.12	3.7558	3.761

5. Comments

The experimental work reflected that the ultimate tensile strength calculated from the two experiments (table 6-7) is 3.76 Kg/ mm^2. This means the actual tensile stress is less than theoretical in data sheet (5.00- 5.50) kgf / mm^2 [3-13]. And this gave us a full confidence that the uPVC pipes will not withstand for long depth.

6.4 Experiment Three: -

Determination of India connecting rod tensile Strength. The tensile strength and elongation of connecting rod of India MarkII determined from tension test carried on the test machine in the strength of materials laboratory at the department of civil engineering, University of Khartoum.

1. Apparatus of the Experiment

A/ Test Machine

Avery Birmingham weighing and counting test machine with maximum capacity 30 ton type A806/ 1474 serial no. E45303 /308. Scale range from 0.1 ton up to 30 ton.

B/ Strain Measurement devices

Strain Gauge Scale range from 0 up to 3000 unit each. 1 unit =0.002 m

2. Test Specimen

Specimens cutting from connecting rod of India Mark11 and Afridev with each with following Dimension:-

Total length of the specimen	600 mm
Diameter of specimen	12 /10 mm (12 mm Dia for Afridev, 10mm Dia. for India MarkII)
Number of specimen	Six number (A_1,A_2, A_3 and B_1,B_2,B_3)

3. Procedure: -

Each test specimens fixed at the upper and lower clamp on the test machine at a distance 100 mm above and below .

1-Zero reading was evaluated.

2-The loads were applied in increments of (tons) to the test specimen.

3-Readings of elongation, contraction measured by used strain gauge and the ruler using strain gauge.

4-Different loads from applied and the elongation recorded in table (6-8)

Table (6-8) Experimental Data

Specimen Designation	Specimen size (mm)	Cross-Sectional area (mm^2)	Applied Load in tons		Strength N/mm^2		Elongation %
			Yield	**Ultimate**	**Yield**	**Ultimate**	
Specimen A1	10.4	85.0	4.500	6.150	529	723	11
Specimen A2	10.2	81.7	5.100	6.100	624	746	12
Specimen A3	10.3	83.4	5.150	6.100	617	731	12
Specimen B1	12.1	115.0	6.550	8.200	569	713	5
Specimen B2	12.1	115.0	7.200	8.600	626	747	9
Specimen B3	12.0	113.1	6.550	7.200	579	636	9

4. Calculation

$$\text{Stress} = \frac{\text{Applied load}}{\text{Cross- section Area}} \qquad \sigma = F/A \qquad 4.5/85 = 529\ N/mm^2$$

F = Applied load
A = Cross section area of the test specimen

Table (6-9). Masses of the Hand pumps moving Parts for different Type of hand pumps

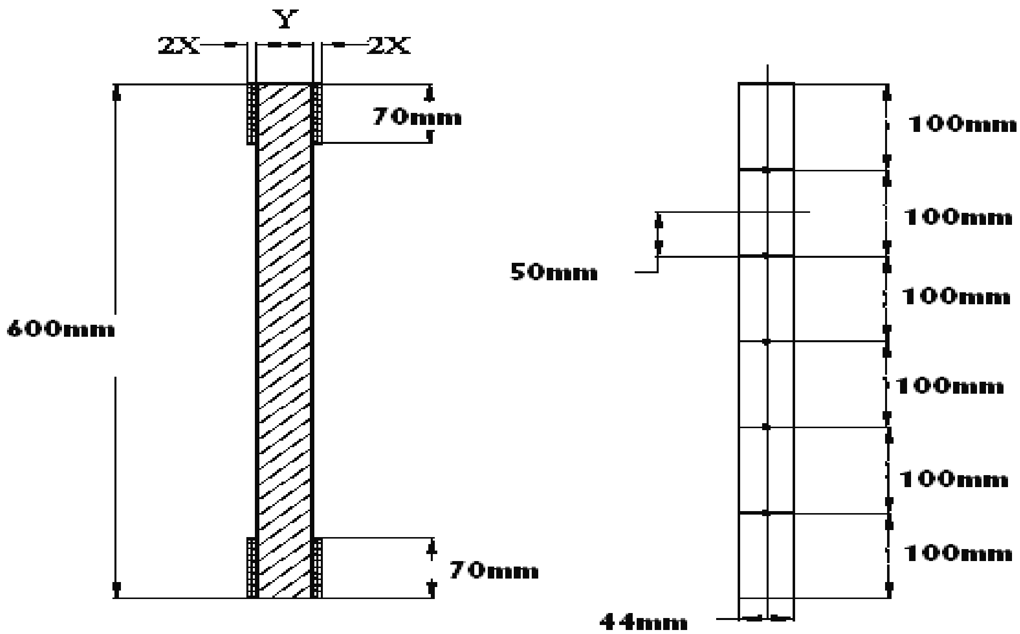
No.	Type of Pumps	Unit	Weight
01	**India MarkII**		
	Connecting Rod	Gram	2727.60
	Upper Valve	Gram	889.60

	Plunger Rod	Gram	449.60
02	**Afridev Pump**		
	Afridev Piston	Gram	83.29
	Connecting Rod	Gram	2172.59
	Plunger	Gram	747.09
03	**Atbara Type (Local Manuf.) (Max. Depth 8.5m)**		
	Plunger Rod	Gram	1209.00
	Suction Valve	Gram	925.00

6. Comments and conclusion

These experimental work put a verified evidence that the elongation of connecting rod is serious and can affect the check valve and upper valve because more elongation means the piston will hit the check valve during operation and breaks sometimes. From the experiment it, appears that the small the diameter of connecting rod the larger in the elongation, (reaches up to 12% in 10mm diameter) but in the large diameters the elongation is about 5-9 % . That means with the large diameters of the connecting rod, along life is expected for the check valve.

From the experimental table (6-8) when used of 10mm connecting rod diameter with length 3000 mm and the applied load 4.500 tons the elongation is 11%. For example in practical terms assume that the selected site is El Hamadia1 village hand pump table (4-2) .The calculation based on the data available at table (4-2) , table (3-4) and the experiment number three result and by using the estimate equation in chapter three, gave the lifting force is equal to 44.531 kgs and the elongation is 3.2 mm, that means for 16 connecting rods the elongation is 51.2 mm (means damaged of the check valve).



X= 4 mm
Y=44 mm
. =point at which strain were measured

Fig. (6-6) Tested Specimen uPVC

Chapter VII

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 Introduction

The analysis of the collected data and the experimental work , reflected a series of guidelines to the solution of interdependent problems of the hand pumps schemes like technical design, community management and well or borehole design. These mentioned problems are firmly the most effective criteria that minimize the output of the water point and reduce efficiencies and even rise the dead time for breakdown. The author arrived at the following conclusion and recommendation:-

7.1. **For India MarkII**

To avoid connecting rod and check valve failure author suggests Following : -

A: The connecting rod of the India Mark II must be replaced by another rod

of a diameter 12mm-14 mm,this will reduce the elongation by 25 %.This will increase the dead load with cost.

B: The under ground assemblies of India MarkII (Cylinder, riser pipes and connecting rod) should be made of non corrosive material instead of stainless steel pipes which are very costly. PVC pipes or FRG materials with the length of 3m. Jointed either by solvent cements or threaded couplers can be used. Use of inner machined threads should be avoided as it is known that causes of leakage and pre-mature failure of the joints due to fatigue Fig (7-3)**.**

7.2- Afridev Hand pump

The experiment showed that the uPVC rising main pipes failure occurred at the joint socket outside diameter 63 mm.To increase the tensile strength, the following modification to the pipe should be done with the following procedure (to raise the tensile strength from 3.76 kg/mm^2 up to 6.41 Kg/mm^2 as shown in Fig. (7-1)):-

I: The pipe is cut off at the right angle at the socket joint then debar the inside edges and chamfer outside ones, chamfered and rounded pipe ends prevent the layer of cement from being removed as the pipe is inserted into the fitting.

II: The pipe end is wiped at the socket with a clean cloth to remove obvious dirt and then the outside of the pipe end and inside of the socket is thoroughly cleaned with a cleaner and absorbent paper.

III: A normal layer of cement is applied to the fitting socket and then a thicker one is applied to the pipe end with a firm brush pressure to cover length of 40 mm. The brush strokes should always be in an axial direction. The handling time for cement is about 4 minutes with ambient temperature range from 25^0C -30 ^{0}C.

VI: The pipe and the joint socket are pushed together immediately with a twisting force and brought into the correct alignment. The pipe and the joint socket are then held short time until initial bonding has taken place. Any surplus cement is removed immediately by using absorbent paper.

V: The same procedure should be applied to another pipe and the joint socket to connect the two pipes together

7.3 Community management: -

Different methods of community management, maintenance were applied by the water projects, rural water corporation and Mahlias but all these methods failed.

The following guidelines are suggested to overcome and raise efficiencies of the hand pumps Fig (7-2).

Consider the **Sheikh** of the village as head of the committee assisted by two members from health and two well-trained mechanics, and one accoutant. The duties of each member are as follows:-

Sheikh: As committee supervisor and undertakes the following responsibilities: -

Store keeper for all fast moving parts for hand pump maintenance

Undertake all the finance responsibilities assisted by an accountant and distribute the water tariff collection according to the following percentage:-

05% to the rural water sector or WES unit

05% to Locality

05% of the total incentive to the village committee

20% to facilities provision of repair part to keep the stock balance. The water tariff balance saves in the village box for any other water services.

Selected fast moving parts per one Hand pump type India or Afridev: -

Rising main	**02**
Connecting rod	02
Check valve	01
Upper valve	01
Pump repair kit	2 kit
Bolt / nut	08
Chain complete	01
Special / standard tool box	01

- To organize regular committee meetings to discuss water related issues.
- To ensure good communication at all levels
- To take up assigned roles and tasks with other committee members

Accountant: To undertake all the financial work after he takes approval from **Sheikh.**

Mechanics: Two well-trained mechanics from the villagers to be trained to maintain the hand pump during breakdown and act as TOT to train other persons.

Water Tariff Collector:

Collects the water tariff and submit the revenue at the end of the day to the committee accountant. And he also trained as a hygiene promoter.

Monitor:-

He is the one who records the breakdowns, spare parts consumption, money collection, money utilization and other water services like mobilization of the community to pay water tariff. Also he is the one who writes the monthly reports to the water sector at unit or Mahlia.

All the reports from Mahlia water sector to be submitted to the water sector or water projects should include the following: -

* Money collected and utilized per month for each community.
* Spare parts consumed and the parts needed to keep stock balance.
* No of breakdowns per month for each hand pump.
* Dead time for water point with full justification

7. 4. The sustainability of the rural water supply system will greatly depend on the local capacity building, by local manufacturing of the pumps and pumps components in the Sudan, establishing facilities for marketing, distribution of the spares.

7.5. The private sector involvement and investment in the sector should be encouraged and facilitated through appropriate policy changes.

7.5 Training:-

Training is one of the essential elements needed for a successful operation and maintenance as well as for future development and sustainable water supply project.

The community has to be supported by training and necessary spare parts and tools. The nominated or selected trainees at each village should be trained in aspects beside operation and maintenance to enable them to encourage their communities towards sounding management through implementation of water charges. Women are the main haulers and providers of water for their families. It is noticed that there are few of every village showed trained woman in maintenance. Efforts should be done to get women involved in maintenance skills since they are the largest sector in rural communities who are responsible for water provision to their houses from available sources. Three days training course is to be conducted, one day on simple theory and other two days on practical. Trainees should have clear idea about routine maintenance, emergency maintenance, preventive maintenance and the difficult jobs in maintenance of hand pumps is the fishing job.

7. 6. The management committee of hand pump installation must be left free to decide on the tariff structure including the mode of payment. The WES units will need to facilitate these decisions especially as regards water charges, which should be based on operation and maintenance system

7.7. – A hand pump well developed to the maximum to ensure enough quantity of water, and avoid clogging later by removing fine sand.

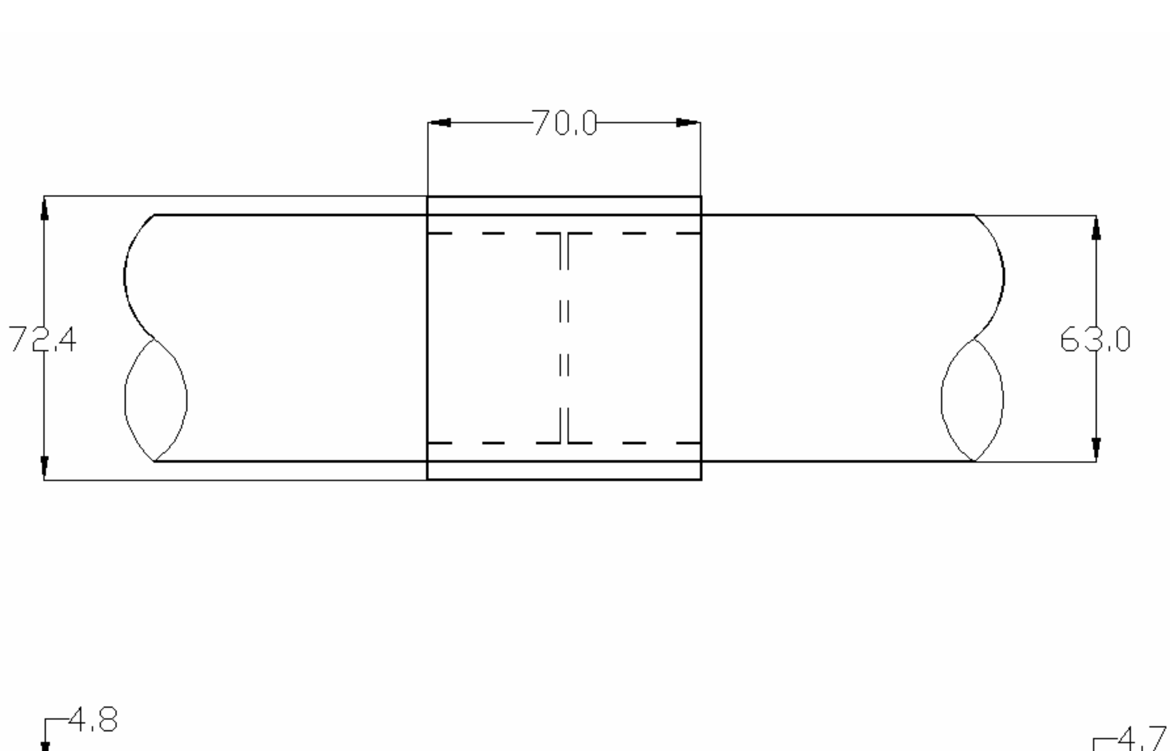
7.8 –The well depth and cylinder setting must be deep enough to cater for anticipated draw down and in low- yielding wells the pump chosen should have design discharge: reasonably matched with the well recharge rate.

7.9. Pumping tests of the wells should include slim borehole (hand pumps). That will give an indication of well yields and draw down for different pumping rates. The draw down of the wells must be avoided by drilling more depth exceeding the propose depth to ensure maximum storage column of water

7.10 The water project and private sectors raise the concept of sale center by establishing many of sale centers in villages / cities and encourage the private sector to avail the warehouse. The water project supplies the spare parts on loan basis with fix paid supply list price to the store keeper, then the profit calculated according to the agreement between the water project and the private sector. Regular visits from water monitor team to the sale center to collect money and top store with repair parts. The private entrepreneurs should be identified, encouraged and assisted to import hand pump spare parts which will be made available to users at sales centre to be established in the local trading centre within the vicinity of the villages.

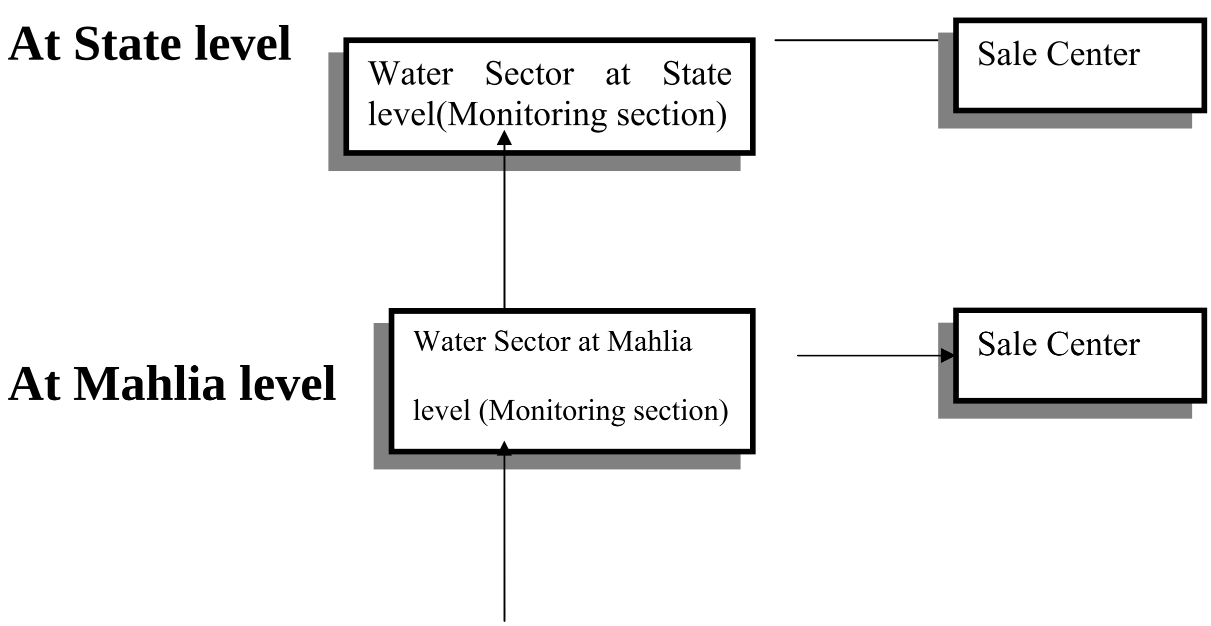
7.11. The Atbara Type Hand pump

This type of hand pumps scattered in Northern Sudan, Dongolla, El Dabba, Karima, and Atbara. The raising main of the mentioned hand pumps better be replaced by PVC pipe instead of Galvanized pipe. The inner parts must be leather rubber instead of plastic rubber.


70.0
72.4
63.0
4.8
4.7

Dimensions in mm

Fig. (7-1) Modification socket joint for two uPVC raising main pipe



At Village level

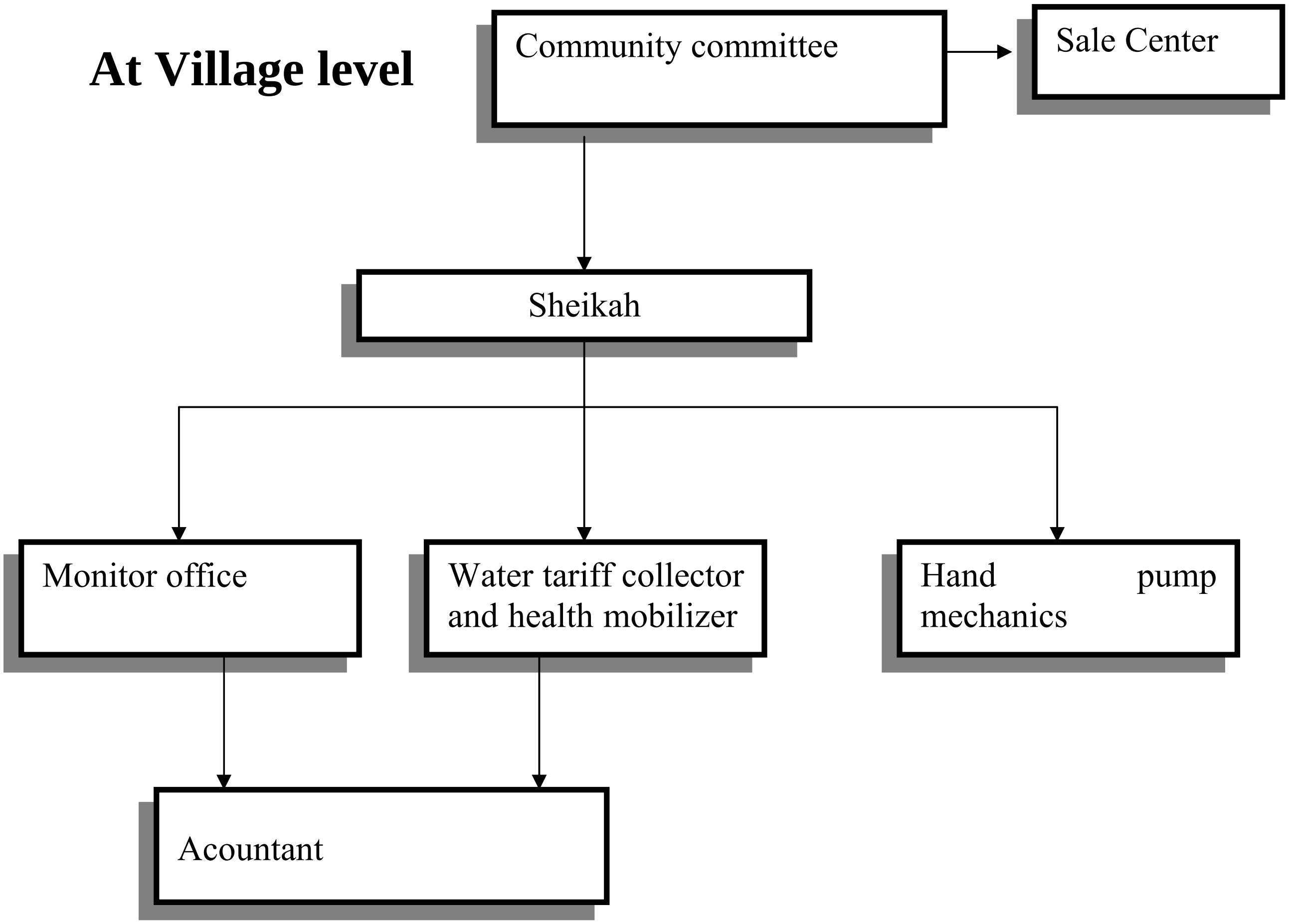


Fig. (7-2) Structure of the Village Committee

Fig(7-3) Installation of the hand pump with uPVC Raising main instead of Galvanized pipe (Dilling, Southern Kordofan)

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Annex / Appendix

Table (1) Part list for India Mark (II) HP

No.	Description	Unit	Qty
01	Inspection cover	No	01
02	Hex nut M12	No	01
03	Hex bolt M12 X 20	No	01
01	Washer M12	No	01
01	Handle assembly	Set	01
06	Chain with coupling	Set	01
07	Chain bolt and nut	No	01
08	Handle bearing (set of two)	Set	01
09	Water tank assembly	No	01
10	Bearing pressing tool	No	01
11	Axle assay with washer and nuts	No	01
12	Third plate	No	01
13	Stand assembly	No	01
14	Cylinder assembly	No	01
15	Plunger rod	No	01
16	Sealing ring for caps	No	01
17	Plunger yoke body	No	01
18	Rubber seating (upper valve)	No	01
19	Upper valve	No	01
20	Pump bucket	No	01
21	Spacer	No	01
22	Follower	No	01
23	Rubber seat retainer (brass)	No	01
24	Rubber seat big	No	01
25	Check valve	No	01
26	Check valve seat	No	01
27	Special tools	Set	01
28	Standard tools	Set	01
29	1¼ gal socket	No	01
30	Spare parts kit	Set	01
31	Connecting rod 12 mm	No	10
32	Rising main gal pipe 1¼	No	10

Table (2) Parts list of Afridev HP

No.	**Description**	**Unit**	**Qty**
01	Pump head Assay with spout	Ea.	1
02	Hex Bolt M16X25	Pcs.	1
03	Hex Bolt & Nut	Pcs.	4
01	Pump Head cover Assay	Ea.	1
01	Handle Assy Front	Ea.	1
06	Handle Assy Rear	Ea.	1
07	Fulcrum Housing Sleeve	Ea.	1
08	Head Fulcrum Pin assy	Ea.	1
09	Fulcrum Pin Sleeve	Ea.	1
10	Hex Nut Special M16	Pcs.	1
11	Lock Pin	Pcs.	4
12	Washer	Pcs.	4
13	Rod hanger Pin	Pcs.	1
14	Rod Hanger Pin Sleeve	Pcs.	1
15	Rod hanger Assy	Ea.	1
16	Rod hanger Bush	Ea.	1
17	Bush Bearing Set	Set.	1
18	Stand Assy	Ea.	1
19	Steel Cone Assy	Ea.	1
20	Rubber compression Cone	Ea.	1
21	Pump Rod assy	Ea.	10
22	Rod Centralize	Ea.	10
23	Pipe centralize	Ea.	10
24	Rising main	Ea.	10
25	Cylinder Assy	Ea.	1
26	Plunger/ Foot valve	Ea.	2
27	Suction Pipe	Ea.	1
28	Valve Bobbin	Pcs.	2
29	U-Seal	Pcs.	1
30	O-Ring Foot valve	Pcs.	1
31	O-Ring Receiver	Pcs.	1
32	Solvent cement	Tube	1

Table (3) Parts list of Atbara Type Hand pump

No.	Description	Unit	Qty
01	Check Valve complete	Ea	1
02	Piston complete	Ea	1
03	Check Valve rubber	Ea	1
04	Piston leather	Ea	1
05	Handle	Ea	1
06	Handle Bearing	Pcs	2
07	Galvanized pipe 2 Inches	Ea	4
08	Galvanized pipe 5 Inches L 600 mm	mm	600

Table (4) Important Parameters of Raw Materials for hand pump:

Physical and chemical properties of Hand pump raw materials are: -

S.No	Material	Chemical& Physical properties	Equivalent Reference Standards
1	Carbon Steel Stock items (Plates, Sections, Bars)	Chemical Properties as per ISO 630 Carbon : 0.21% (max) Sulphur : 0.065% (max) Phosphorus : 0.065%(max) Nitrogen :0.01%(max) Physical Properties Tensile Strength :340-470N/mm² Yield Strength :235N/mm²	DIN 17100 ST 37-2 IS 2062 SKAT/HTN
	Cold Rolled Sheets	**Chemical Properties per IS 513 Grade**: Deep Drawing (DD) Carbon :0.10%(max) Manganese :0.45%(max) Sulphur :0.035%(max) Phosphorus :0.035%(max) Physical Properties Tensile Strength :270-370 MPA Yield Strength :250MPA (max) Elongation : 32%(min) Hardness HRB 65	
	Pipes	**Chemical Properties as per DIN 17100**, **ST**-37-2 Sulphur :0.060 (max)	**SKAT/ HTN**

		Phosphorus :0.060 (max) Carbon :0.25 (max) The maximum permissible variation of Sulphur and phosphorus shall be 0.005% Physical Properties Tensile Strength: 250-540Nmm² Yield Strength :175 N/mm²	ISO 4200 **DIN 1615** IS 1239
	Bright bars	Chemical Properties Same as in 1. a (Carbon steel). **Physical Properties as per IS 9550 Grade:** 2 Tensile Strength :470-690 MPA Elongation : 13% (min)	**DIN 668** IS 9550
	Forgings	**Chemical Properties as per IS 2004 Class3**. Carbon :0.25-0.35%; Silica :0.15-0.35%; Manganese :0.60-0.90%; Sulphur :0.04%(max) Phosphorus : 0. 04% (max) Physical Properties Tensile Strength :490N/mm² (min) Yield Strength: 279 N/mm² (min) Elongation: 21%(min) Hardness: 120 BHN(min)	
2	Stainless Steel Bright drawn rods (AISI 304)	Chemical Properties as per DIN 17400-1.4301 Carbon :0.08% (max) Chromium : 18%- 20%; Nickel :8.00-12%; Silicon :1.00%(max) Manganese: 2.00% (max); Phosphorus : 0.045% (max); Sulphur :0.03%(max) Physical Properties Tensile Strength: 590N/mm² (annealed) Yield Strength: 240 N/mm² (annealed)	IS 6603 SKAT/HTN Hand pump Specification
3	Bright rods bars(AISI316)	Chemical Properties as per DIN 17400-1.4401 Carbon :0.08%(max) Chromium : 16.00-18.50 % Nickel : 10.50-14.00% Molybdenum :2.00-2.50% Silicon :1.00% (max) Manganese :2.00% (max) Phosphorus : 0.045% (max) Sulphur :0.03% (max) Physical Properties	

		Tensile Strength :700N/mm² Yield Strength : 450 N/mm²	
3	Forgings AISI 304	Chemical Properties Same as 2.a (stainless steel rod) Physical Properties as per DIN 17440-1.4301 Tensile Strength: 500-700N/mm² Yield Strength: 195 N/mm² Elongation: 40 % (min)	IS 6603
4	Forgings AISI 316	Chemical Properties Same as 2.b (stainless steel rod) Physical Properties as per DIN 17440-1.4301 Tensile Strength :510-710N/mm² Yield Strength : 205 N/mm² Elongation : 40 % (min)	IS 6603
		Chemical Properties as per DIN 17660- 2.0460:CuZn 20 A12 Copper :76.0-79.0% Aluminum :1.8-2.3% (max) Nickel : 0. 1% (max) Lead :0.07% (max) Iron :0.07% (max) Arsenic :0.07%(max) Magnesium :0.005 Phosphorus:0.01 Manganese :0.1 Total impurities :0. 1%(max) Zinc : remainder Physical Properties as per DIN 17671,part 1&11 Hardness: 80-110 H.B. Tensile Strength: 330 N/mm	
5	Brass Liner	Chemical Properties as per DIN 17660- 2.0470:CuZn 28 Sn1 Copper :70.0-72.5% Zinc : remainder Arsenic :0.02-0.035% Iron :0.07% (max) Manganese :0.1%(max) Nickel :0.1% Tin :0.9-1.3% Phosphorus :0.01% (max) Lead :0.07% (max) Others :0.1% (max)	IS 407
6	Stainless Steel Sleeve	Chemical Physical Properties Same as 2.a stainless steel (bright drawn)	
7	Components made	Tensile test: Destructive test (9500 Newton) on a	SKAT/

	from Polyamide (PA6.6 NC) and Polyacetal (POMNC Hompolymer)	few pieces per production batch, and nondestructive test (5000 Newton) on all plunger/foot valve assemblies Molding Weight: compare with reference weights Molding Color: Discoloration not desirable Molding Surface finish to be Smooth Molding Sectioning: Pits, voids and discontinuities not acceptable	Injection Moulding Manual
8	Components made from Nitrile Rubber		IS 8683 SKAT/ HTN Rubber guidelines
9	uPVC pipes	Chemical Properties The material shall contain substantially of polyvinyl chloride. Effect on Water: Lead (Ist Extraction): 1.00mg/It Lead (3rd Extraction): 0.30mg/It Dialkyltin:0. 02mg/It Cadmium (for all :0. 001mg/IT the three extractions) Mercury (for all :0. 01mg/IT the three extractions) Others toxic substances (3rd extractions)	DIN 19532 DIN 7748 Part 1 DIN 8061 DIN 8062 IS 4985 IS 12235
10.	Solvent Cement	1. Common solvents used: THF, MEK, Cyclohex. 2. Cements containing toluene and polystyrene not to be used* 3. Polymer employed should not contain any plasticizers or any reground material* 4. Recommended polymer content in solvent cement is 20-30%* 5. Standard for testing methods: ISO – 7381-1, ASTM D2-564, BS 5350-P.B2 6. Packing: Recommended size for use in the field, 250 ml in metal tins or tubes. Packing should be sealed air- tight and opaque.	ISO 7387-1 (Testing methods)
11	Fasteners Carbon Steel	Chemical and Physical Properties Same as Table 1- 1a above.	ISO 898 DIN 17100 IS 2062
12	Stainless Steel	Chemical and Physical Properties Same as above.	DIN 17400 IS 6603

Refer (G.Prakash,SKAT 1995)

Standards used in the Hand pump Specification

Standards	Description
DIN 668	Bright round steel: Dimensions Permissible deviations according to ISO
DIN 1615	Welded circular un-alloyed steel tubes not subject to special requirements.
DIN 7748PI	Plastic molding materials: unplasticized. Polyvinyl chloride (uPVC) molding; Materials classified and design.
DIN 8061	Unplasticized polyvinyl pipes: General quality requirement and testing.
DIN 8062	Unplasticized polyvinyl chloride (uPVC, PVC) pipes: Dimensions.
DIN 17440	Stainless steels: Technical delivery condition for plate and sheet, hot rolled strip, wire rod, drawn wire, steel bars, forgings and semi-finished products.
DIN 17660	Copper-zinc alloys (Brass), (Special brass): Composition.
DIN 17671 P1 & 2	Wrought copper and copper alloy tubes: properties.
ISO 630	Structural steels. Equivalent DIN 17100
ISO 4200	Plain end steel tubes, welded and seamless- General tables of dimensions and masses per unit length. Equivalent DIN 2458
ISO 7387 P1	Adhesives with solvents for assembly of uPVC pipe elements- Characterization- Part 1: Basic test methods.

BS 2751 Specification for general-purpose acrylo- nit riles rubber compounds.

Table (5) Price List For India Mark (II)

No.	Description	Unit	Qty	Import price in (US)	Local Price At state In (SD)
01	Inspection cover	No	01	1.15	2040.00
02	Hex nut M12	No	01	0.02	1000.00
03	Hex bolt M12 X 20	No	01	0.02	150.00
01	Washer M12	No	01	0.17	5000.00
01	Handle assembly	Set	01	14.50	10000.00
06	Chain with coupling	Set	01	3.50	1000.00
07	Chain bolt and nut	No	01	0.17	130.00
08	Handle bearing (set of two)	Set	01	0.94	1500.00
09	Water tank assembly	No	01	5.86	7500.00
10	Axle assay with washer and nuts	No	01	0.84	1500.00
11	Third plate	No	01	0.94	500.00
12	Stand assembly	No	01	11.60	15000.00
13	Cylinder assembly	No	01	16.50	15000.00
14	Plunger rod	No	01	0.94	1000.00
15	Sealing ring for caps	No	01	0.10	300.00
16	Plunger yoke body	No	01	0.75	1500.00
17	Rubber seating (upper valve)	No	01	0.04	100.00
18	Upper valve	No	01	0.45	900.00
19	Pump bucket	No	01	0.12	500.00
20	Spacer	No	01	0.05	1000.00
21	Follower	No	01	0.83	1000.00
22	Rubber seat retainer (brass)	No	01	0.31	500.00
23	Rubber seat big	No	01	0.02	100.00
24	Check valve	No	01	0.38	1500.00
25	Check valve seat	No	01	0.08	1000.00
26	Special tools	Set	01	75	27000.00
27	Standard tools	Set	01	70	25000.00
28	1¼ gal socket	No	01	0.42	100.00

29	Spare parts kit	Set	01	1.90	4000.00
30	Connecting rod 12 mm	No	01	1.35	2000.00
31	Rising main gal pipe 1¼	No	01	4.40	4000.00
32	Connecting Rod Socket	No.	01	0.06	500.00
33	Head Assembly	No.	01	16.50	10000.00

Table (6) Price List For Afridev Hand pump

No.	Description	Unit	Qty	Import price in (US)	Local Price At state In (SD)
01	Pump head Assay with spout	Ea.	1		10000.00
02	Hex Bolt M16X25	Pcs.	1	0.09	150.00
03	Hex Bolt & Nut	Pcs.	4	1.02	250.00
01	Pump Head cover Assy	Ea.	1		2800.00
01	Handle Assay Front	Ea.	1		6000.00
06	Handle Assay Rear	Ea.	1		2500.00
07	Fulcrum Housing Sleeve	Ea.	1	1.20	1500.00
08	Head Fulcrum Pin assay	Ea.	1	1.60	1500.00
09	Fulcrum Pin Sleeve	Ea.	1	0.75	2000.00
10	Hex Nut Special M16	Pcs.	1	0.09	200.00
11	Lock Pin	Pcs.	4	0.04	25.00
12	Washer	Pcs.	4	0.07	25.00
13	Rod hanger Pin	Pcs.	1	1.30	1200.00
14	Rod Hanger Pin Sleeve	Pcs.	1	1.17	2500.00
15	Rod hanger Assy	Ea.	1		3000.00
16	Rod hanger Bush	Ea.	1		1000.00
17	Bush Bearing Set	Set.	1	0.43	350.00
18	Stand Assy	Ea.	1		11500.00
19	Steel Cone Assy	Ea.	1	1.50	1200.00
20	Rubber compression Cone	Ea.	1	0.90	500.00
21	Pump Rod assy	Ea.	10		1500.00
22	Rod Centralize	Ea.	10	0.17	100.00
23	Pipe centralize	Ea.	10	0.35	200.00
24	Rising main	Ea.	10		3000.00
25	Cylinder Assy	Ea.	1	21.00	10000.00
26	Plunger/ Foot valve	Ea.	2	1.20	700.00

27	Suction Pipe	Ea.	1	1.50	1400.00
28	Valve Bobbin	Pcs.	2	0.15	150.00
29	U-Seal	Pcs.	1	0.09	60.00
30	O-Ring Foot valve	Pcs.	1	0.05	25.00
31	O-Ring Receiver	Pcs.	1	0.05	25.00
32	Solvent Cement	Tube	1	1.15	650.00
33	Rope in (Roll)	M	320	16.00	

Table (7) Price List for Atbara Type Hand pump

No.	Description	Unit	Qty	Local Price at state In (SD)
01	Check Valve complete	Ea	1	1000.00
02	Piston complete	Ea	1	2000.00
03	Check Valve rubber	Ea	1	500.00
04	Piston leather	Ea	1	800.00
05	Handle	Ea	1	3000.00
06	Handle Bearing	Pcs	2	1000.00
07	Galvanized pipe 2 Inches	Ea	4	7000.00
08	Galvanized pipe 5 Inches L 600 mm	mm	600	2000.00

Table (8) List of Maintenance Tools for India Mark II Hand pump

No.	Tool Name	QTY
01	Tank Pipe Lifter	01
02	Self Looking Clamp	01
03	Coupling Spanner	01
04	Connecting Rod lifter	01
05	Handle Axle Punch	01
06	Lifting Spanner	03
07	Chain coupler supporting tool	01
08	Connecting Rod vice	01
09	Crank Spanner	01

Table (9) List of Maintenance Tools for Afridev Hand pump

No.	Tool Name	QTY
01	Socket Spanner	01
02	Open Double ended Spanner 17/19	01

03	Fishing tool	01

Table (10) List of Maintenance Tools for Afridev Hand pump

No.	Tool Name	QTY
01	Open Spanner	01
02	Ring Spanner	01
03	Open Spanner	01
04	Ring Spanner	01

Table (11) Pump General Information

Model	Description	Suitable for water level range (m)	Min. ID of bore well (mm)	Capacity (Lit/hour)	Pump Rod/ connecting Rod Dia. (mm)	Riser pipe (ND)
				(Iph)	Material / (Dia-mm)	
SHALLOW WELL HAND PUMP FAMILY						
SW1-65/150	Cast iron shallow well hand pump	Up to 7	75	1500	MS G (12)	GI (32/40)
SW2-75/150				2000	MS GI (16)	u.P.V.C (32/40)
SW3-90/150				2850	MS GI (16)	GI, (40)
INDIA MARK II DEEP WELL HAND PUMP FAMILY						
IM.II	India mark-II	15 to 45	110	1150	MS GI (12)	GI/32
IM II	India mark III VLOM	15 to 45		1150		GI/uPVC, 65
IM III-MOD	India mark III VLOM modified	14 to 45		600		GI/uPVC, 50
IM IV	India mark II extra deep well	45 to 90		900		GI 32/50
IM II-GHV	India mark II modified (Ghana version) with 50mm& 62.5mm, all brass cylinders	15 to 45	90	600 & 900	SS (12)	Light weight SS 32
IM II-SAM	India mark II modified (Zambia version) with 76mm stainless steel cylinder	15 to 45	100	1650	SS (12)	SS 32

AFRIDEV DEEP WELL HAND PUMP						
AFD	Afridev	15 to 45	110	1350	Various options available	uPVC 63
AFD-MOD	Afridev with brass cylinder	15 to 45	110	1350	Various options available	GI 76.5

HAND PUMP OPTIONS AVAILABLE WITH STANDARD ASSEMBLIES	
Stand/pedestal assembly options	Three legs type
	Flange type
	Concrete block type
Connecting rod assembly options	Galvanized MS connecting rods, 10mm, 12mm & 14mm in dia.
	SS connecting rode conforming to AISI 304 grade
	SS connecting rode conforming to AISI 316 grade
	Fiber reinforced glass, light weight, 10mm connecting rod with machined brass/ SS connectors or friction lock metal connectors
	Threaded couplers suited to 10mm dia. And 12mm dia. MS /SS rods.
	Forged and machined Eye & Hook tool – less rod connectors in MS or SS as per rod material.
Cylinder assembly Options	µ PVC jacketed Brass/ SS liner with extractable plastic molded plunger and Foot Valve assembly.
	µ PVC jacketed Brass/ SS liner with Universal Cylinder components in brass, gunmetal or molded engineering plastic.
	Brass / Stainless Steel Cylinders with flush caps, with 50, 63.5,76 & 100 mm Ids.
Riser pipe options	Standard supply is with "B" Class Gal. pipes, 32 mm ND with IM II, 65 mm ND or 50 mm ND with IM III (standard & Modified)
	Stainless Steel Riser Pipes 38 mm OD with IM II, 70 mm OD with IM III.
	µ PVC Riser Pipes, 50 mm ND, with cemented 2 pieces or 3 pieces couplers for IM III modified. 32 mm ND for IM II. Additional Hydraulic Anchors for these pumps in extra deep applications.
	µ PVC Riser pipes, 32 mm, 50 mm, & 65 mm ND with Stainless steel couplers for IM II, IM III & IM III Modified.
	µ PVC Riser pipes, 50 mm ND, with bell ends for Afridev & IM III Modified – u3. For standard IM III, 75 mm OD pipe with Bell joints.

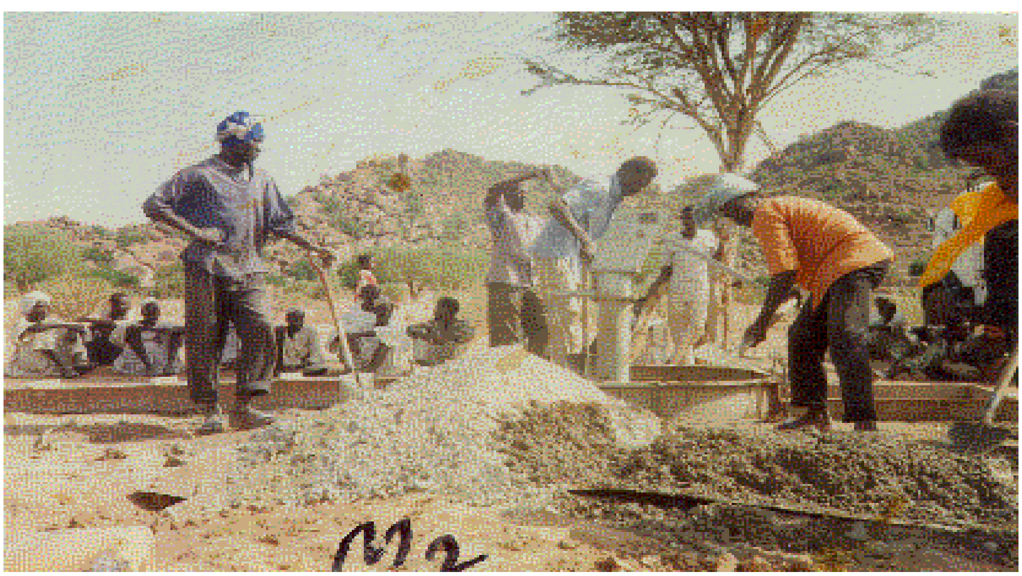
Table (12) Fiber Glass Mechanical Properties

Parameter		**Mechanical Properties**					
Diameter	mm	6 mm	10 mm	13 mm	16mm	19mm	25 mm
Weight /Length	g/m	77.0	162.3	284.1	434.4	596.8	836.0
Tensile Modulus of Elasticity	Gpa	45	45	46	46	42	45
Ultimate tensile strength	Mpa	827	796	839	794	666	
Allowable tensile stress	Mpa	203	195	196	201	153	158

Ultimate strain in tension	%	1.8	1.7	1.8	1.8	1.6	1.7
Shear strength	Mpa	221	221	213	206	204	139
Guaranteed Design Tensile strength	Mpa	812	778	782	755	612	

Afridev hand pump under maintenance
(Khartoum – El Salama primary school)

Afridev cylinder under. Test (El Slama primary school, Khartoum)



Installation of hand pump (Northern Kordofan)

India MarkII Hand pump in operation after maintained
(Northern Kordofan**)**